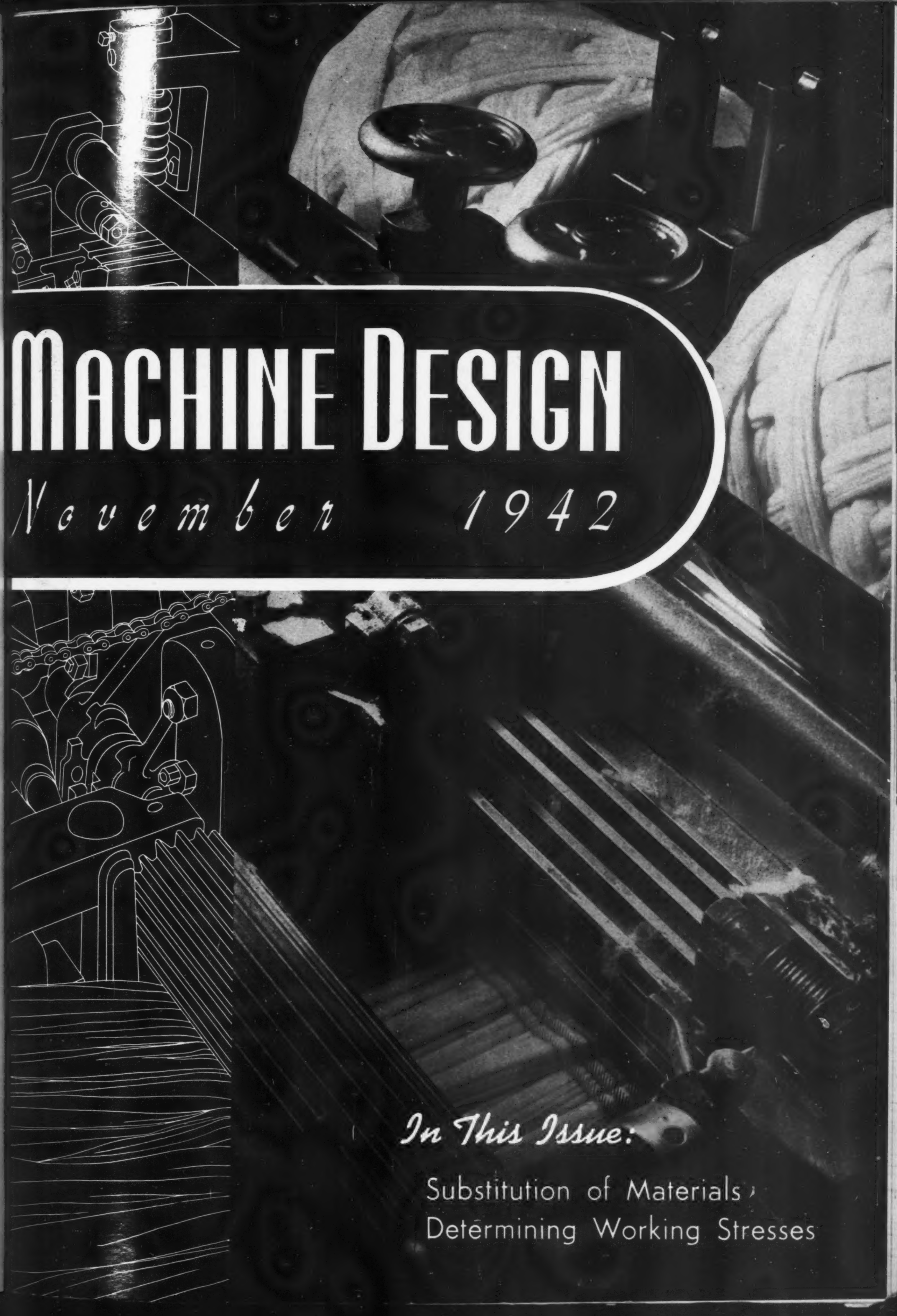

MACHINE DESIGN

November 1942

In This Issue:

Substitution of Materials

Determining Working Stresses

MACHINE DESIGN

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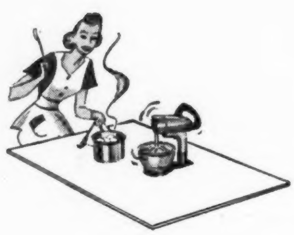
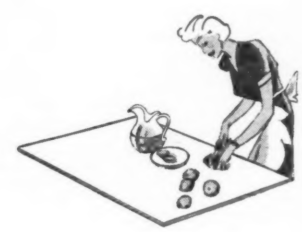
a Libbey-Owens-Ford Product

TEMPERED VITROLITE

comes to the rescue of the kitchen table





THERE'S little about the work surface of a kitchen table to arouse one's scientific or engineering interest. Yet, when the basic material from which it is made is suddenly sent to war, a major replacement problem is created.

The new material must answer a multiplicity of demands. It must be strong and durable, highly resistant to thermal and physical shock, sanitary and easy to clean, nonporous, impervious to acids, and most important today, *abundant.*

Here's a combination of physical and chemical requirements as exacting as many modern industrial material specifications. The problem, however, can be solved successfully through the controlled characteristics of glass. In this case, *Tempered Vitrolite* provides the answer.

In the development of this product, our engineers began with a standard Libbey·Owens·Ford product, Vitrolite. This well-known glass is used in modern store fronts, and as wainscoting for bathrooms and kitchens. Its surfaces are smooth, sanitary, nonporous and easy to clean. It is stainproof and resistant to all common acids. It is opaque, made in the purest white, or in a wide range of other attractive colors.

Just one step was necessary to make Vitrolite the perfect kitchen table top. By a special process we tempered it and endowed it with an iron constitution. Through this process it becomes so strong that it will support the weight of an average family. It is amazingly resistant to physical impact. It stands thermal shock so well you can place it on a cake of ice and pour hot molten lead on the topside without causing a crack.

Because of its unusual work surface advantages, don't be surprised if you see *Tempered Vitrolite* in many applications other than the top of a kitchen table.

This is an added example of how modern know-how is fitting glass to serve in ever-increasing usefulness. Maybe one of the many types of Libbey·Owens·Ford flat, bent or tempered glass products will solve your problem. Libbey·Owens·Ford Glass Company, 1361-A Nicholas Building, Toledo, Ohio.

L O F

LIBBEY·OWENS·FORD

QUALITY *Flat Glass* **PRODUCTS**

Topics

According to A. A. Brainard of the Philadelphia Electric Co., "A ray of light shouldn't be allowed to turn up its toes and die because it falls on a flat surface. If given half a chance a light ray will bounce back like a rubber ball from ceiling, floor, walls and machines repeatedly. Thus valuable electric power produces illumination that does its job extremely well over and over again."

♦

New tires which will give 10,000 miles service if driven at speeds below 35 miles an hour will be produced in quantity as soon as the government regulations are completed. Each new tire will contain only four ounces of crude rubber for cementing the plies, the remainder will come from the nation's rubber scrap pile. The tire will be suitable for recapping.

♦

Rabbit brush, a common yellow flowering plant contains rubber of excellent quality. Yield by flotation is usually about 2½ per cent rubber from plants 6 to 10 years old.

♦

Appointment of a committee of engineers and scientists to determine the manner in which the projected Office of Technical Development should be set up within the War Production Board, and to define the scope, functions and methods of operation which the office should have, was announced recently by Donald Nelson. Members of the new committee are Webster N. Jones, Carnegie Tech; Lawrence W. Bass, New England Industrial Research Foundation; Oliver W. Buckley, Bell Telephone Laboratories; Col. Clarence E. Davies, Ordnance Dept.; Ray P. Dinsmore, Goodyear Tire and Rubber Co.; Admiral J. A. Furer, Navy; Jerome C. Hunsaker, M.I.T.; H. W. Graham, Jones & Laughlin Steel Corp.; S. D. Kirkpatrick, Chemical and Metallurgical Engineering.

♦

Because electrolytic tinning saves 60 per cent over hot-dip methods there will be twenty-six lines in operation throughout the country by July 1943, most of them designed to handle 36-inch strip at speeds above 600 feet per minute. Copper oxide rectifiers will be used in some instead of the large motor-generator sets generally used to supply the low voltage needed. The rectifiers are just as efficient, take less space and, since they have no rotating equipment, require much less maintenance.

♦

Electronic device automatically signals when ice forms on airplane wings and sets the rubber deicers to work. This protects the pilot, who, when flying at night, is not aware of a dangerous condition until the ice is too thick to be broken off.

♦

Auto graveyards now are producing about 20 per cent of all the iron and steel scrap being used by our wartime steel industry. During the last six months, the remains of more than a million automobiles have been moved to the furnaces. The government is hoping to maintain this rate for some time to come, according to the War Production Board.

♦

Replacing tin in collapsible tubes for tooth paste, shaving cream, etc., special Lumarith look exactly like metal ones and can be squeezed in the same way. The tubes are produced by extrusion, the top is capped with a shoulder and threaded neck of injection-molded Lumarith, and the cap is phenolic. At present metal clips will be used to seal the ends but machines are being developed to fold and heat seal them obviating the use of any metal.

♦

Pneumatic spreader principle has been applied to stoker designs so that steam-size coal is conveyed to the furnace by a stream of air. The fine coal burns in suspension while the heavier pieces form a shallow bed on the stoker grates.

♦

Induction heating of thermoplastics has been designed to utilize heat, developed by high hysteresis and eddy current losses, as the plastic material is passed through a hollow magnetic element.

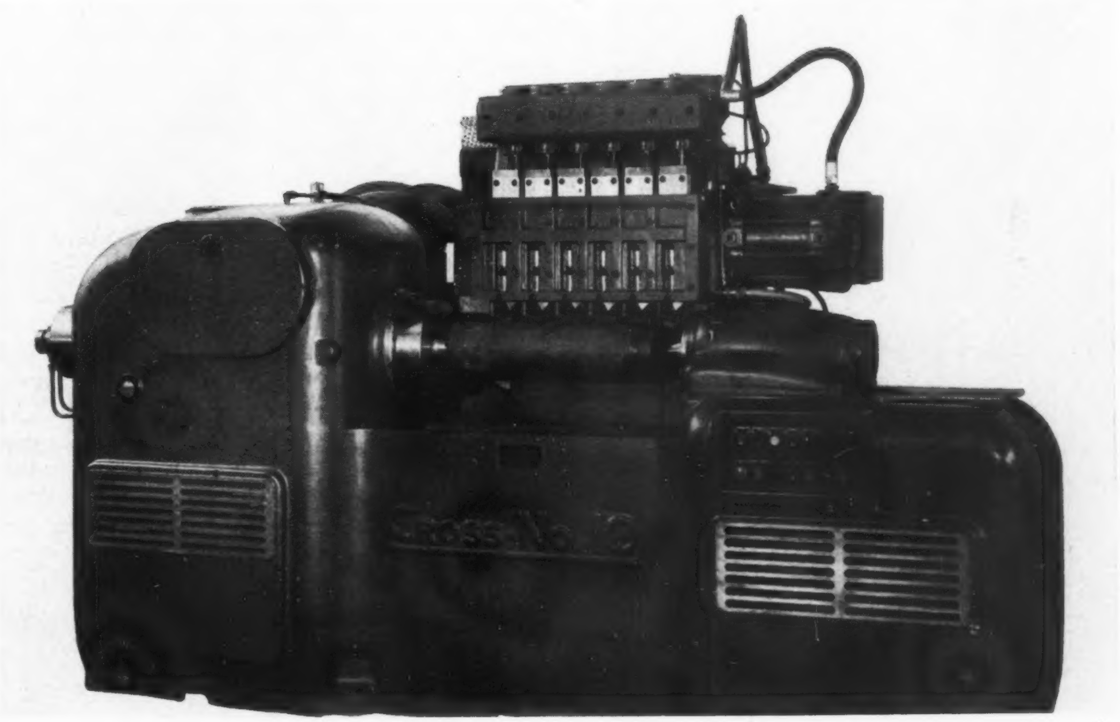


Fig. 1—Vertical tool slide facilitates loading and unloading of shell blanks

Shell Lathe Design Jumps Ahead

By Kurt Tech
Chief Design Engineer
Cross Gear & Machine Co., Detroit

WARTIME conditions in manufacturing plants have created a need for special-purpose equipment possessing characteristics not found in conventional machines. Thus, in view of official statements that 70,000 additional women will be required in industry by June, 1943, new designs must properly incorporate features that will facilitate handling of machines by women operators. Also the changeover from limited to mass production of ordnance necessitates a higher degree of efficiency than can be attained with all-purpose machine tools.

For the efficient machining of forged alloy steel shell

blanks, the lathe illustrated in *Fig.* 1 has recently been developed and is now in production. Essential points which must be considered in designing machines of this type include the following:

1. Ease of loading and unloading
2. Full automatic pushbutton operation
3. Ample power and rigidity to accommodate multiple tooling
4. Clean exterior design for extra safety
5. Compactness for close grouping on production line
6. Pressure lubrication of all moving parts, metered according to degree of lubrication required
7. Hydraulic actuation of work clamping devices to speed operations
8. Hydraulic cushioning of tools to avoid undue wear on cams

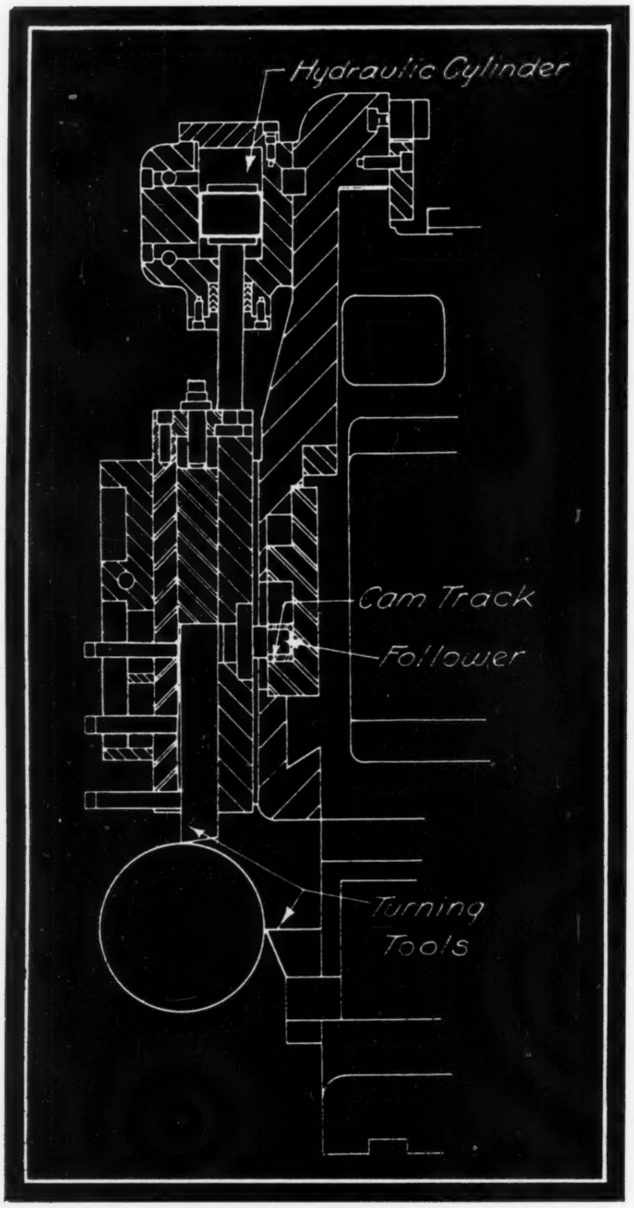


Fig. 2—Thrust along tool is transferred to lathe bed through hydrulic cylinder, relieving load on cam

In this list, items 1, 2, 4 and 7 might be considered as design features facilitating operation by women.

Design and construction of a machine in which all the above features are incorporated calls for painstaking development. In the case of this lathe the design evolved to its final conception over a period of years, with several experimental models preceding the present production unit.

Conventional shell turning lathes with multiple tooling usually have a bank of horizontal turning tools in front of the work, with facing and cutoff tools also mounted horizontally at the rear. Early models followed this design but it was found that this disposition of tools interfered with convenient loading and unloading of the work and also made necessary a considerable overhang of the tailstock center, with consequent lack of rigidity. To overcome this difficulty the idea was conceived of mounting the tool slide in a vertical position over the work and supporting it on a continuation of the frame of the machine extending up from the rear, *Figs.* 1 and 2. End facing tool and cutoff tool slides were retained in a horizontal position feeding in from the rear.

This construction permitted reducing the overhang of the tailstock center appreciably and thereby increased the rigidity of the suspension many fold. The tailstock is mounted on hardened and ground steel ways, *Fig.* 3, and includes a live spindle mounted on antifriction bearings. Hydraulic rapid traverse moves it to the work and engages under predetermined pressure, clamping in position automatically with a positive mechanical lock.

Vertical tool slide carries six separate turning tools, the path of each being determined by traverse of a hardened and ground roller over a cam slide which is attached to the tool slide support frame. Vertical thrust of the tool is transferred to hydraulic cylinders mounted above each tool arm, *Figs.* 1 and 2, result being that the rollers virtually "float" on the cam with a balanced pressure, minimizing stress and wear on the cam. The tool slide travels on scraped cast iron ways at the upper and lower edges of the supporting frame, with the lower edge of the slide dovetailed over the way so that all cutting forces are directed down to the bed of the lathe,

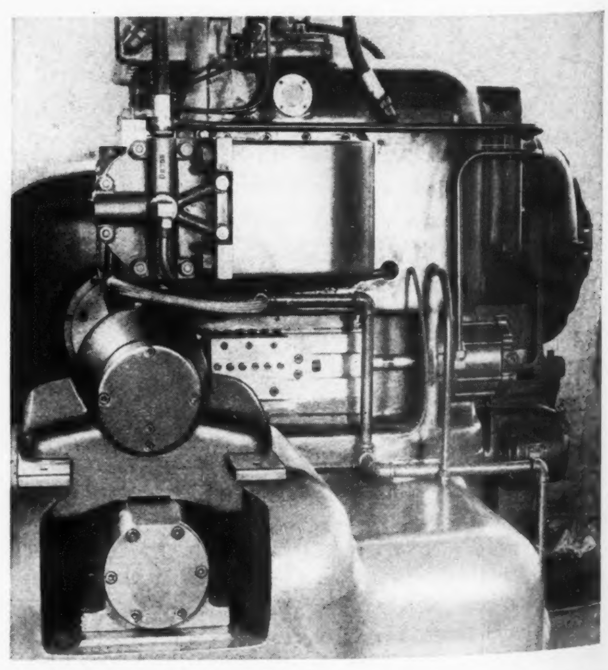


Fig. 3—End view shows mounting of tailstock and horizontal cylinder and slide for end facing tool

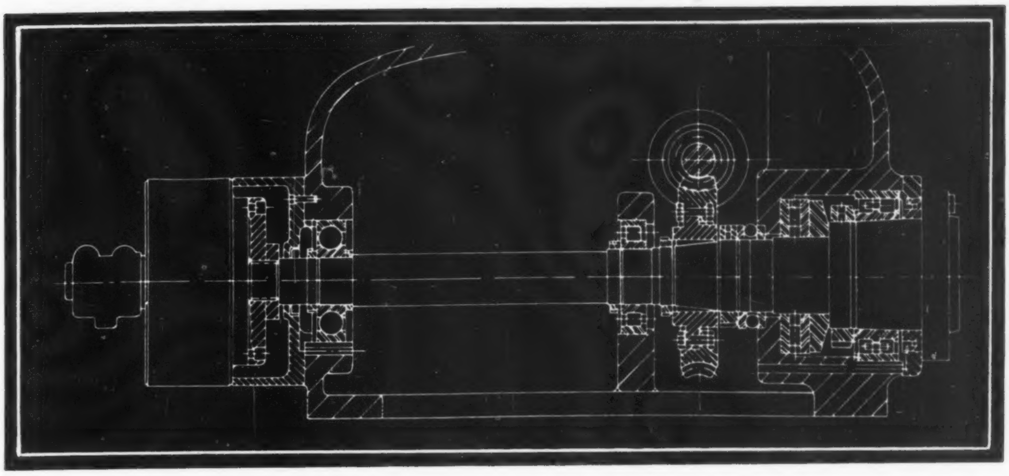


Fig. 4—Hollow headstock spindle is driven by an enveloping worm gear and is mounted on three radial bearings with two thrust bearings located so as to allow differential expansion

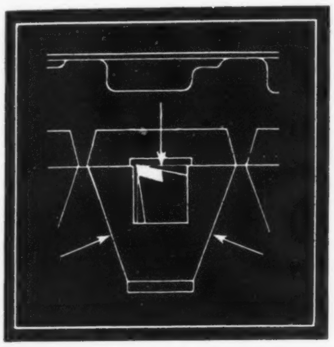


Fig. 5—Above—Tool holders with two angular bearing surfaces are designed to balance cutting pressure. Wedge action increases rigidity as cutting pressure increases

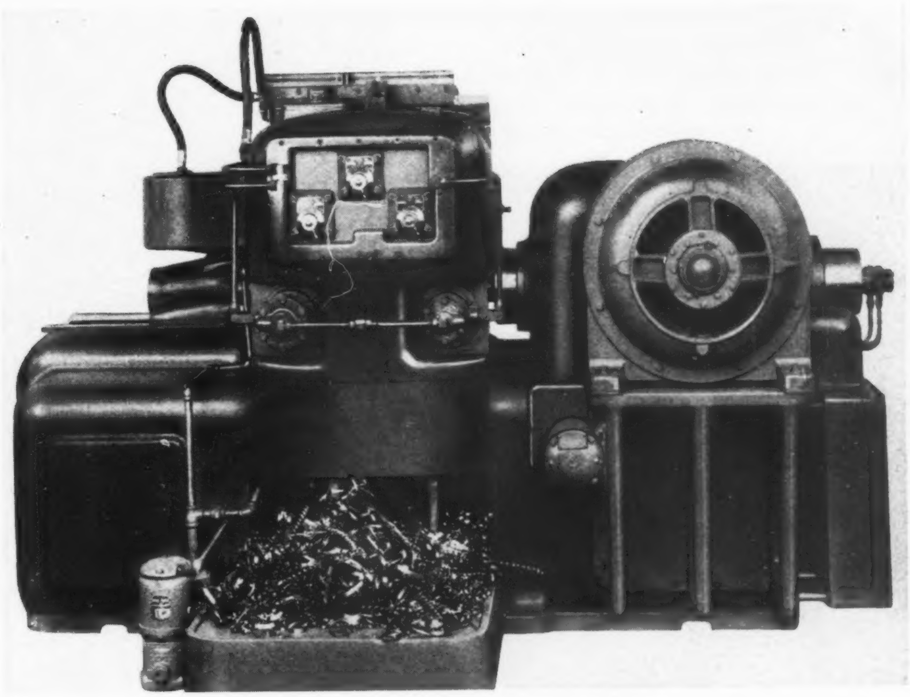


Fig. 6—Right—Rear view shows drive motor mounting. Also shown are dials for independent adjustment of turning tool and facing tool hydraulic feeds

avoiding the danger of the tools being lifted away from their support. All tools are supported close to their cutting edges so that overhang can be kept to a minimum.

Main drive spindle in the headstock is carried on two straight roller bearings and a ball bearing to absorb radial loads, plus two thrust bearings to absorb thrust loads exclusively, *Fig.* 4. Also alloy steel, this spindle is hollow to permit passage of a control arm from a hydraulic cylinder on the outside to the expanding arbor on which the shell blank is mounted. Both headstock and tailstock bearings are adjustable from the outside.

Novel design has been developed for tool holders, which are machined alloy steel. Vertical bearing surfaces are tapered on their sides at an angle of about 30 degrees to balance cutting pressure and to prevent tool twist, vibration and chatter, *Fig.* 5. These angular bearings thus provide a wedge action which increases their rigidity as the cutting pressure increases.

With eight carbide-tipped tools functioning simultaneously and with cuts running as deep as ½-inch at times, considerable power is necessary to operate the machine. Main drive motor is 100-horsepower and is mounted on a pedestal bolted to the rear frame of the machine *Fig.* 6. This mounting permits direct drive of the clutch shaft, eliminating the need for any belts. The clutch shaft, through a system of pickoff gears and enveloping worm drive gear, powers the headstock spindle. Clutch is of the multiple-disk type and is enclosed in the headstock.

No levers or handles are employed, full control being through a front panel, visible below the tailstock in *Fig.* 1 and also in *Fig.* 7, on which appear eleven control buttons, a three-way switch and two signal lights. Metal plates over each clearly indicate its function. The pushbuttons are grouped for operation in sequence from left to right, the top row being used for starting and the lower row for stopping. With the switch in automatic position, the unclamp button may be pushed and the work placed in the arbor. Actuating the tailstock in, clamp and clutch in buttons makes the cycle start button operative and illuminates a green signal light. After the tool cycle has been completed, the green light disappears.

To free the interlocking controls for setting up the machine, the switch is set at hand operation, illuminating

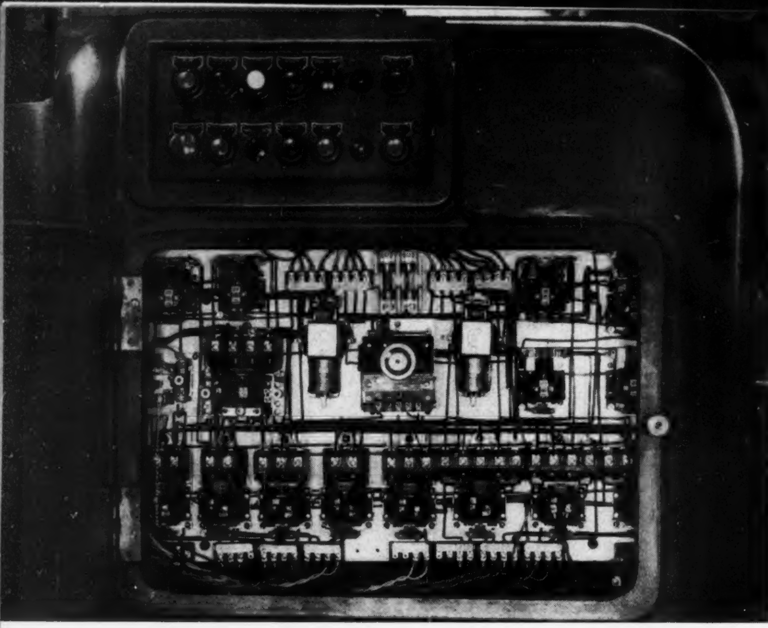


Fig. 7—Cover swung back to reveal centralized wiring panel. Dial near center adjusts timing control

Fig. 8—Below—Flange-mounted multistage hydraulic pump for actuating feed mechanisms is geared to the main driveshaft in the headstock

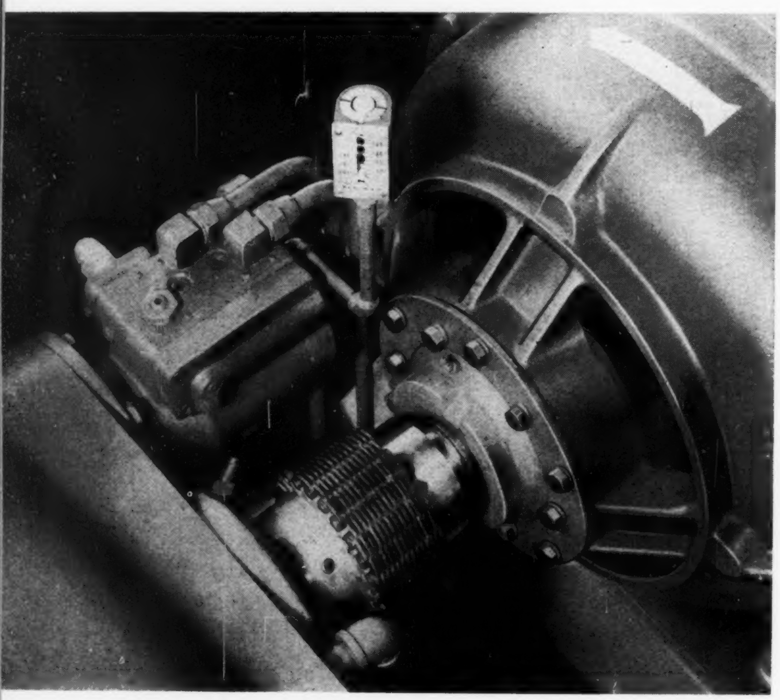
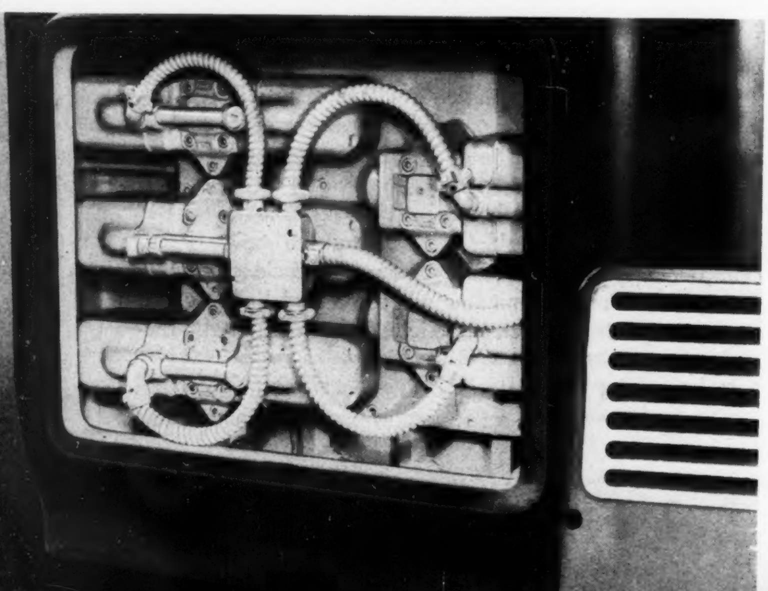


Fig. 9—Below—Compactly contained behind front panel, hydraulic valves are mounted on manifold to reduce piping and danger of leaks



an amber signal light, whereupon any one of the other controls may be operated. An emergency stop button arrests all motion of the machine at any point in the cycle. Two other stop buttons are provided for stopping the tool slide motor and the main drive motor respectively.

Directly below the control panel and accessible through a ventilator door is the centralized wiring panel, laid out in accordance with National Machine Tool Builders Association standards, *Fig.* 7. In the center of this panel is a precision dial adjustment for setting the electric timing control which regulates the automatic cycle of the machine.

This control system has twelve separate hydraulic cylinders, all supplied through a single flange-mounted multistage hydraulic pump placed outside the headstock next to the motor driveshaft and driven therefrom, *Fig.* 8. These hydraulic cylinders are used for the following actions: Clamping the work (actuating expanding arbor); shifting the clutch; traversing the tailstock; feeding six turning tools; operating the tool slide; and operating the facing and cutoff tools (two cylinders). Hydraulic valves are panel mounted on a hydraulic manifold to eliminate much of the piping otherwise required and to minimize leaks which occasionally develop in piping systems, *Fig.* 9. This manifold is readily accessible behind a vent door in the headstock.

Chip Disposal Facilitated

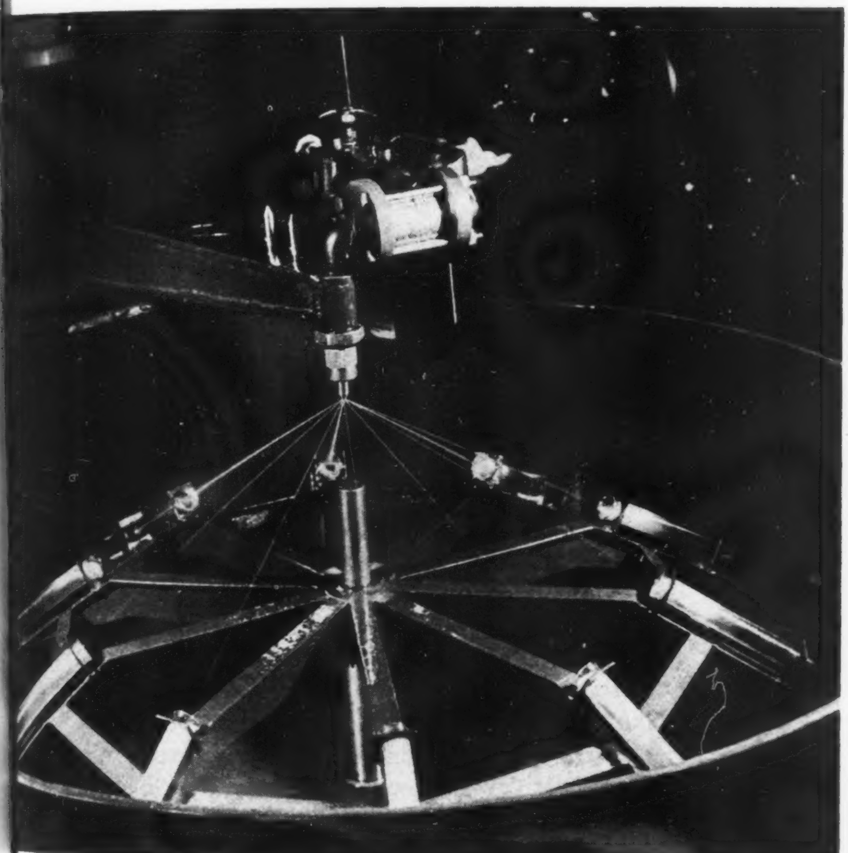
Coolant is supplied by a pump to a manifold casting mounted around the tool posts, from which individual pipes or spigots carry the cutting fluid to a point just ahead and in front of each cutting tool. Similar spigots supply coolant to the facing and cut off tools. A separate coolant spigot is positioned to wash chips and turnings down an inclined chute at the rear of the machine on to a disposal pan, shown in *Fig.* 6. Chips may be shoveled from this collection pan at intervals, or the machine may be arranged for conveyor disposal of chips, in which case a centralized coolant supply system may be adopted to handle a battery of machines. Coolant is drained from the chip pan, filtered and recirculated into the supply system.

Automatic force-feed lubrication supplies all moving parts with metered quantities of lubricant through two separate oil pumps. Tailstock ways, tool slide ways, cam and roller system, as well as both tailstock and headstock spindles and gears receive a constant measured supply of lubricant. In the case of the headstock, one pump supplies all lubrication to gears and bearings, with individual lines to each bearing plus a spray over the entire system. The second pump furnishes lubricant to other moving parts outside the headstock.

Frame is heavily ribbed cast iron, with all corners and edges smoothly rounded. Absence of all protruding handles and levers enhances the smoothness of the contours and at the same time is an important safety factor, particularly with unskilled operators.

Although a special-purpose machine, this lathe has a certain flexibility of operation, accommodating shells up to about 36 inches in length and between 5 and 10 inches in diameter. Pickoff gears provide a spindle speed range of from 110 to 450 revolutions per minute. Evidence of compactness is the fact that floor space of only 135 by 85 inches is required.

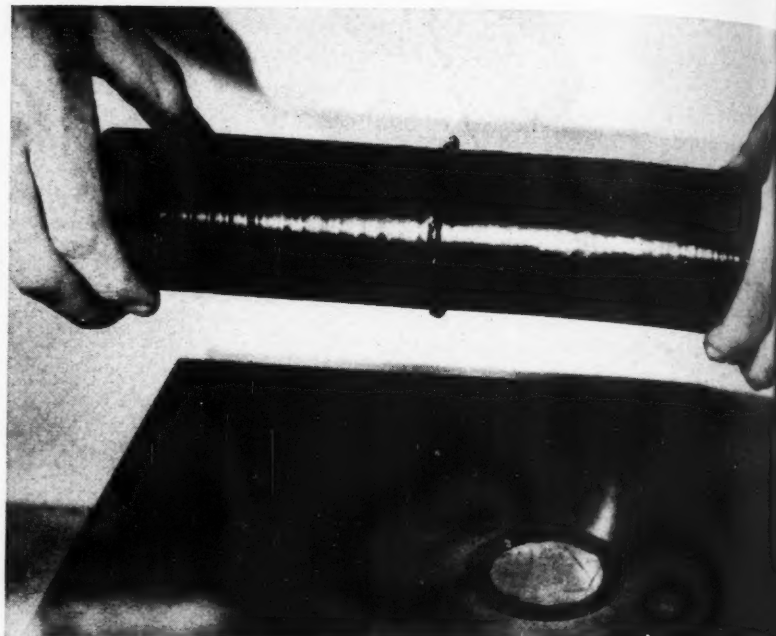
Scanning the field for IDEAS



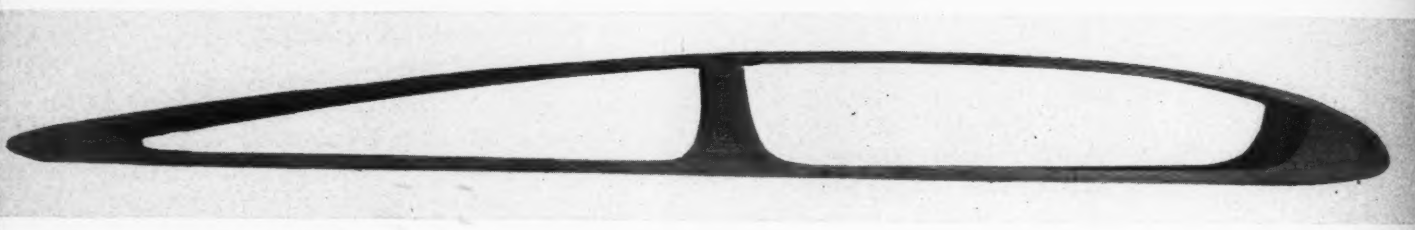
Under-surface flaws and defects in heat treatment such as hard or soft spots are readily detected by a simple magnetic test, below, developed at Westinghouse Research Laboratories. Suitable for symmetrical steel parts such as bearing races, the test involves rotating the part at high speed after it has been completely demagnetized to remove all traces of residual magnetism. Then it is highly magnetized so that flux extends outward from the surface being tested. This flux is explored with an electromagnet. Variations in the field, caused by defects, induce a voltage in the coil which is indicated on an oscilloscope. Because the piece is rotated synchronously with

Accuracy of diesel injection nozzles both as to exact position of holes and their size is quickly determined in the testing arrangement shown above. Developed by the Cooper-Bessemer Corp., the nozzle is fitted into an overhanging arm, fuel oil being forced through at tremendous pressure. If the holes which are about .008-inch in diameter are not accurately drilled, the streams will not be directed into all of the ten test tubes. Also if they are oversize or undersize the quantity delivered into the tubes in a given time will disclose the error. In this way better diesel performance is assured.

the cathode ray sweep, faults which show up as dips can be marked off in degrees and easily located on the test piece. In automatic production testing, the visual indication could be converted to an audible signal or automatic rejection for segregation of faulty pieces.



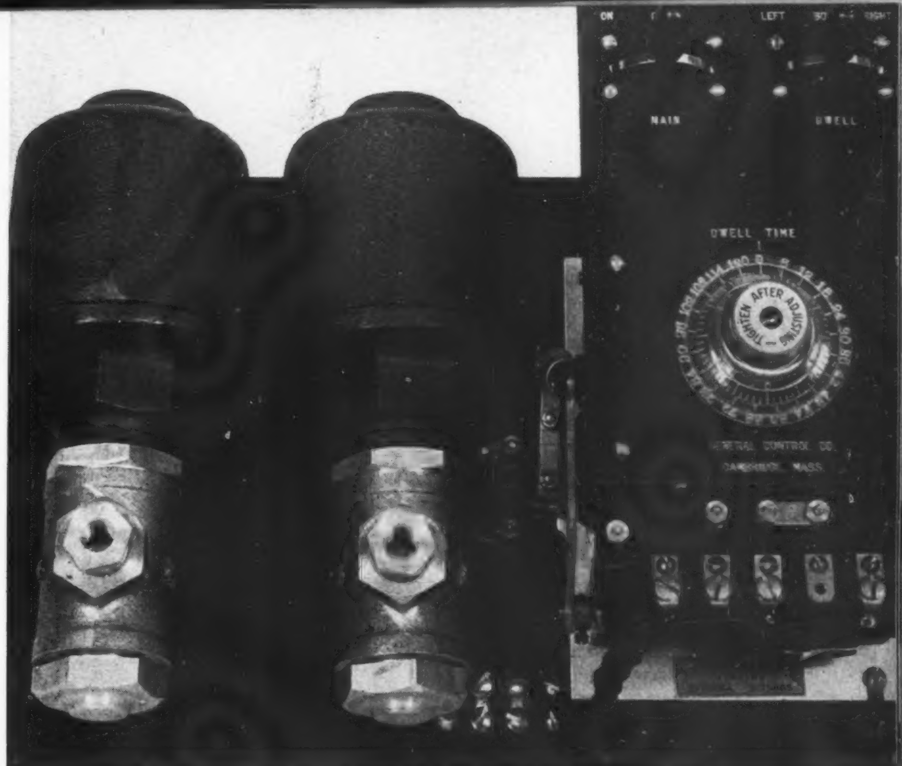
Welding of thermoplastic piping develops joints with greater strength than the original pipe itself. As shown in the illustration at right Saran, an aliphatic-chloride thermoplastic, has been held on a hot plate heated to 350 to 400 degrees Fahr. until molten material appeared. Ends were placed together in proper position and allowed to cool for ten seconds. Entire operation involves only 45 seconds.

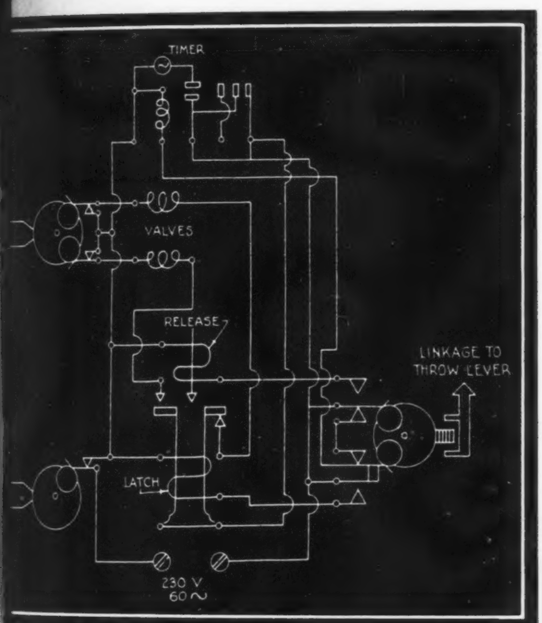


Ribbed-steel forgings are utilized to form two-piece airplane propeller blades for new Army fighting planes. Developed by the Aeroproducts Division the blade, as shown in section above, has a brazed steel sheet preformed over the main forging which involves various stages of heating, cooling and drawing to complete the process. An extremely light unit with high strength is obtained in this way. In the completed propeller, only 13½ pounds or 4 per cent of the entire weight are aluminum, practically 90 per cent of the remainder being forgings. In addition to being lighter than other methods of fabrication, these steel blades have a greater resistance to corrosion and abrasion as well as better physical properties.

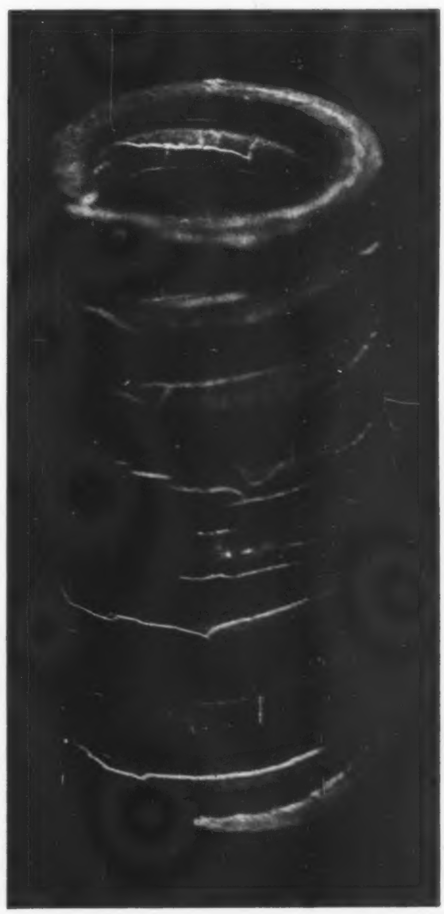
High-speed miller, utilizing a portable tool, rapidly faces surface for a wing fitting for a "Lightning" P-38 as shown at left. Guides on each side of corrugated fittings hold a bracket on a 50,000 revolutions per minute air driven tool with an end cutting rotor. In addition to using available equipment, this time-saving development is typical of our aircraft industry's ability to employ methods of turning out more planes at a faster rate than any other nation on earth.

Dwells at either or both ends of a traverse in a hydraulic system are often desirable, especially for limit switch operation. To provide readily selected dwells of any duration up to 120 seconds, General Control Co. has developed the unit illustrated at right. Designed especially for use on grinders, it prevents the formation of unground sections at the end of traverse which might cause wheel breakage. As shown in the schematic diagram, the timer circuit controls either valve singly, both or neither depending on the position of toggle switches at the left.





For nonmagnetic materials, markings are made by penetration of a highly fluorescent liquid into the surface openings. After removing the surface liquid and dusting with a dry powder, the fluorescent material emerges from the faults by capillary action. These cracks are then outlined brilliantly when viewed with black light. For magnetic materials the test is similar to magnaflux inspection except the ferromagnetic powder is fluorescent. Discontinuities such as inclusions of nonmagnetic materials in addition to cracks are highly visible by this method.



Fluorescent indications of incipient cracks provide methods for inspecting parts having highlights or other surface irregularities which would make inspection difficult by ordinary tests. Also fluorescent methods are available for detecting flaws in nonmagnetic materials. In this method, developed by the Magnaflux Corp., appearance of cracks is indicated in the photographs at the right showing shrink cracks in a brass ring and surface cracks in a helical spring.

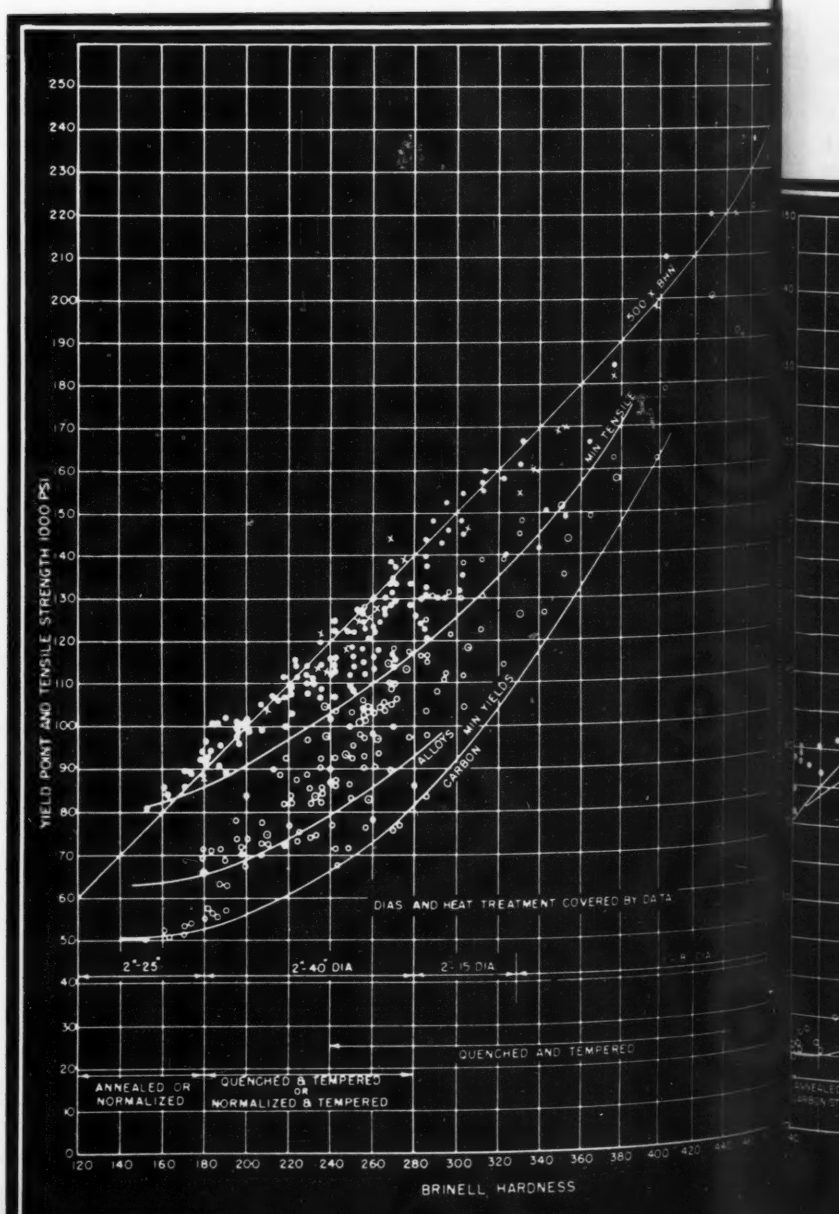
Substituting Materials in Gear Design

By E. J. Wellauer
The Falk Corp.

IN SUBSTITUTION, cognizance must be given the fundamental requirement that service performance of the material be equal to the task. Times such as these require an exchange of production facts capable of being used as a guide for the solution of similar problems by others.

The problem confronting the gear metallurgist and engineer is one of using available materials and specifying a proper heat treatment to provide adequate physicals. The diameters encountered range from a fraction of an inch to large, heavily-loaded mill pinions, such as the one illustrated in *Fig.* 1. In the industrial gear field, the volume does not allow extensive experimentation or testing on an individual application. Once the choice of substitute material is made, the part must respond to heat treatment and perform satisfactorily in the field.

Before approaching the problem of the individual effect of alloys, it is desirable to study those available at the present time. The alloys now available in increasing tonnages and which before long will be the only types available, with few exceptions in the armed services, are the National Emergency or "NE" steels. The analyses of the NE steels were included in the table published in MACHINE DESIGN for October, 1942, Pages 150 and 151. It is to be noted that most of them contain low amounts of chromium and nickel, these being the scarce alloys, with molybdenum and particularly manganese higher than usual.



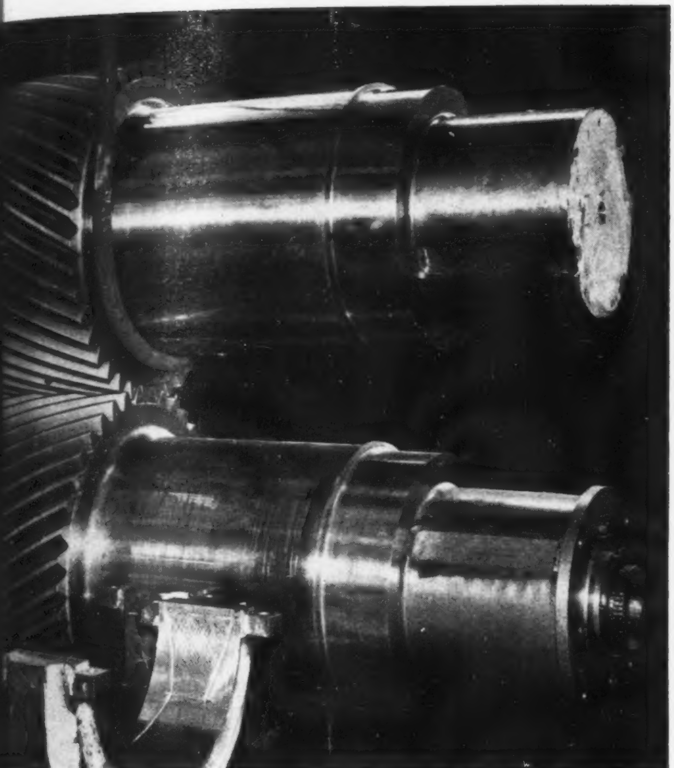
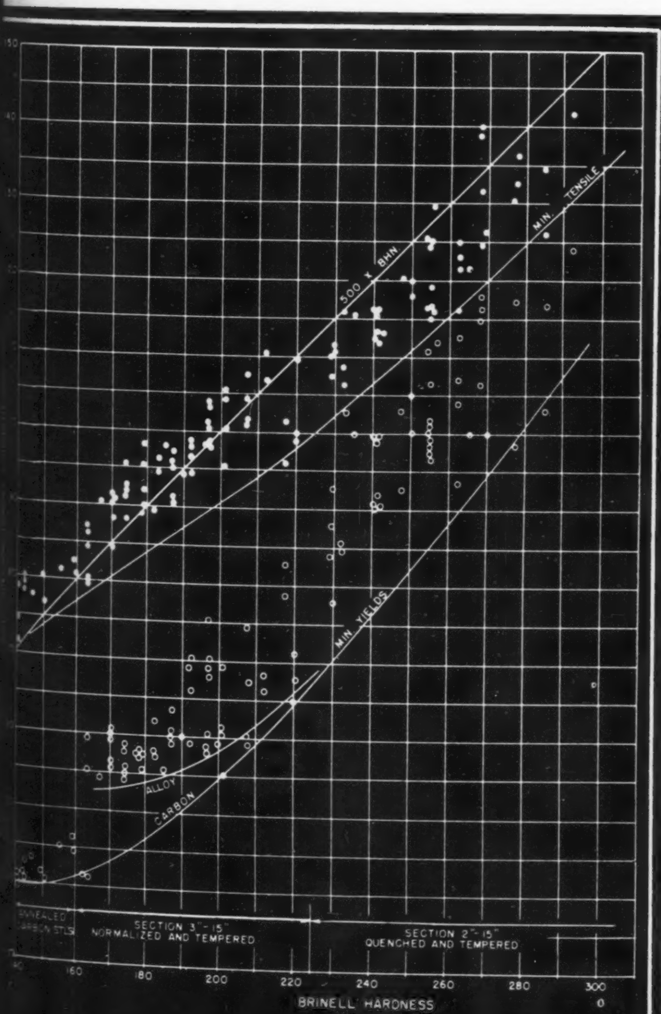


Fig. 1—Above—Industrial gear substitution problems involve sizes ranging up to the forty-inch alloy steel heat treated pinions illustrated

Fig. 2—Left Below—Relation between brinell hardness and tensile properties for rolled and forged carbon and alloy steels. Crosses and circled dots denote NE steels

Fig. 3—Below—Relation between brinell hardness and tensile properties for cast carbon and alloy steels



A good portion of the low nickel and chromium contents can be obtained as residuals in the melt. The NE 9400 and NE 9500 series were expressly designed to require no additional alloying for chromium, nickel, and molybdenum, and quantities being secured as residuals in carefully selected melt scrap.

The author has for a number of years maintained a record of the engineering properties of various alloys with varying heat treatments for the purpose of interpreting the true effects of these alloys on production and service. To these have been added results obtained on NE steels used for gears, shafts, etc. Brinell hardness has been used as a common denominator because of its additional importance in gear wear, production inspection, etc.

Of primary importance to the design engineer is the tensile strength of steels, upon which profile durability and fatigue strength are directly dependent. There is a direct relation of tensile strength to brinell hardness for steels, regardless of alloying content. For small sizes under 2 inches, carefully heat treated and tested under laboratory conditions, the tensile strength is equal to 500 times brinell hardness number with errors of less than 10 per cent.

The design engineer will question such data on small sections, since he must limit his design to figures secured in production. Variations in tensile strength against brinell hardness are shown in *Fig.* 2. These data represent tests made from prolongations of actual production bars and forgings of a wide variety of sizes, heat treatment, and alloy contents. NE steels conform to the general trend for the particular hardnesses. The plotted trend includes the inaccuracies inherent in commercial tensile and hardness testing, and the effect of variations in materials, such as cleanliness, segregations, etc. Even with all

BECAUSE of current restrictions on the use of alloy steels this article, based on a paper presented at the recent semiannual meeting of the A. G. M. A., is of timely interest. The article supplements information on NE steels included in earlier issues of MACHINE DESIGN and focuses attention on the necessity for considering these steels as well as the plain carbon types

these variables, a definite relation between tensile strength and brinell hardness is secured, indicating that alloys have little effect upon the strength of gear steels, provided appropriate hardness can be secured with a normal heat treatment.

For small sections fully hardened, the yield strength is directly proportional to the brinell hardness. The ratio is not affected by the alloys present. However, for large sizes considerable variation exists, dependent upon the alloy content in relation to the heat treatment and greatly influenced by the quality of the steel, test speeds, test bar finish, and associated variables. The trend of yield vs. brinell hardness is also plotted in *Fig.* 2. For larger sizes,

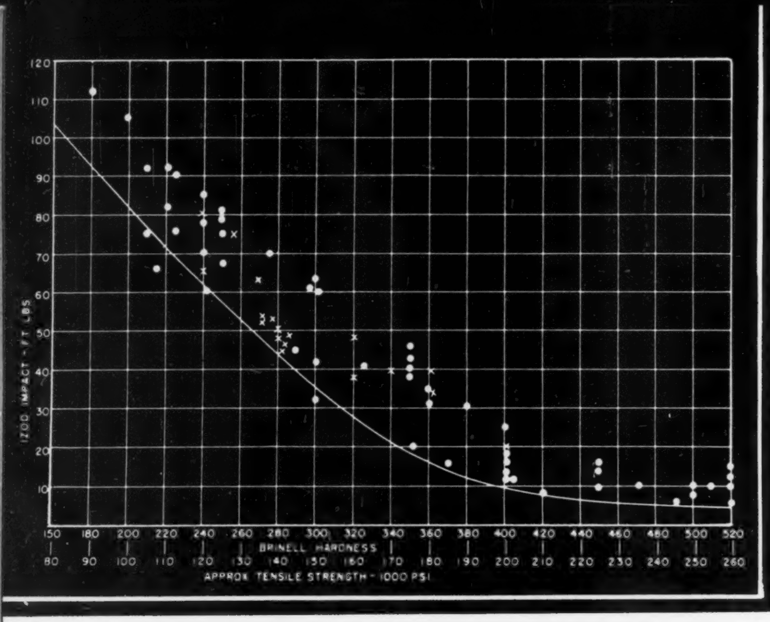
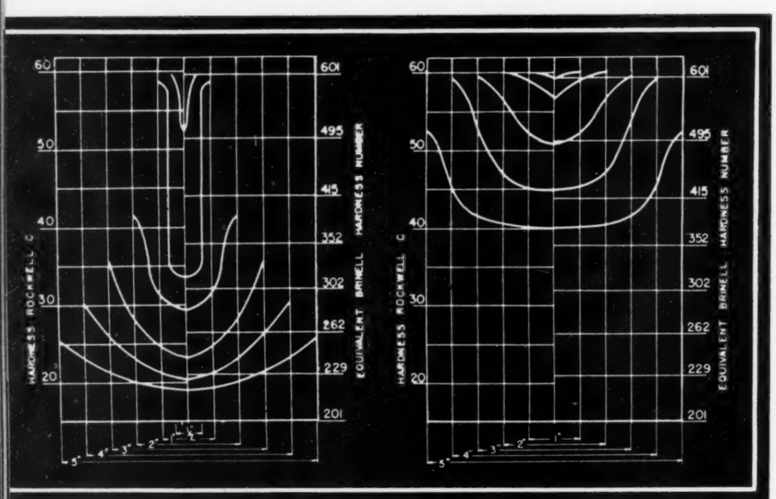


Fig. 4—Impact test is correlated with brinell hardness for various alloy steels (dots) and NE steels (crosses)

Fig. 5—Transverse hardening curves obtained by sectioning water-quenched round bars. Results for SAE 1045 are shown at left, for SAE 4140 at right



the alloys produce a higher yield for a given hardness, although the variations in minimums is of minor importance because failure in gears is normally by fatigue.

The same relationship expressed for bars and forgings holds true for steel castings, as shown in Fig. 3. Although no definite trends for standardized cast steels have been made to utilize low alloys, the same end results have been brought about by Government restrictions and by cooperation between foundries and consumers. The Falk corporation has always used an intermediate manganese-low molybdenum cast steel, normally around 1.25-1.50 manganese with .20 molybdenum. Over a period of a year or more, gears have been placed in service having 1 to 1.15 manganese with molybdenum as low as .07, secured as a residual. Except for the lower hardenability, expected with reduced alloying and compensated for in heat treatment, no difference in the tensile strength-brinell hardness ratio was noted.

The relation of fatigue or endurance limit to tensile strength has been found by numerous investigators to be directly proportional to the ultimate strength and independent of the alloys. The effects of internal stress, sharp notches, cleanliness, surrounding media, etc., have a more profound influence than any effect of alloys.

Toughness of steel is difficult to determine quantitatively, although a degree of measurement is secured by the per cent elongation and reduction in area of the tensile test and by the Izod and Charpy impact tests. The Izod or Charpy impact test is the better criterion of impact resistance for gear steels, since a measure of "notch sensitivity is also provided. The variation of Izod impact with brinell hardness is plotted in *Fig.* 4 The data have been accumulated from production tests on 18 different quenched and tempered alloys ranging from low carbon carburizing steels to highly alloyed, fully hardened steels. For reference purposes, results with NE alloy steels have been included. It is of interest that the points include some low alloyed sulphurized steels having values within the mean of the range rather than at the low side as might be expected, although it is known that transverse impact might show a different trend. Obviously, hardness or tensile strength (500 × BHN) is a governing factor when definite differences in toughness are desired.

Sometimes hardness has been used as a criterion for the measurement of wear. Hardness for such a measurement is not quite correct, since the wear for a given hardness is dependent upon the metallographic constituents and the alloy content. For a given hardness a material rich in carbide formers (carbon, chromium, manganese and molybdenum) will show greater wear resistance than a steel low in these elements.

Because the modulus of elasticity is constant for steel, regardless of the alloying elements present, the problems of elastic deformation, so important in gear work, are not influenced by the general use of lower alloyed steels.

The ability of steels to absorb energy internally seems to be somewhat affected by the atomic arrangement of alloys in steel. However, the high values of stress necessary in large volumes of material have not made this property of definite value in gearing applications.

Because of the critical function of accuracy in gearing as related to load capacity, the question of distortion of gears heat treated after cutting is considered an engineer-

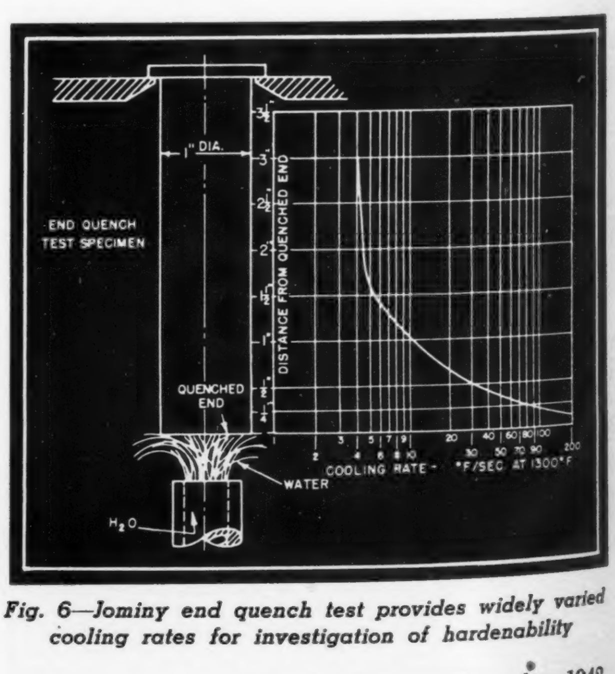


Fig. 6—Jominy end quench test provides widely varied cooling rates for investigation of hardenability

[1]These factors will be covered in the course of MACHINE DESIGN's current series of articles "Wartime Metallurgy Conserves Strategic Materials".—ED.

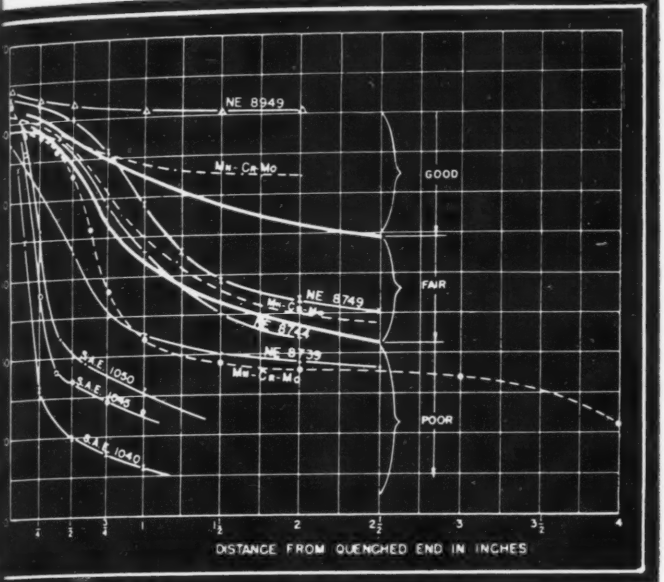


Fig. 7—End quench hardenability curves show relative response to heat treatment of various steels

ing problem. In fact, the engineer must compensate his calculated ratings for the lesser accuracy of gears hardened after cutting. Final grinding after cutting can partially rectify heat treating distortions, although other difficulties prevent full utilization of the high accuracy secured on gears cut before heat treatment.

Distortion obtained in gears heat treated after cutting is directly a function of the severity of the quench necessary to produce proper hardness. This severity is dependent upon several metallurgical factors involving critical cooling rates, transformation temperatures, etc., which cannot properly be presented within the confines of this discussion.[1] It cannot be expected that the NE steels with lower alloy contents will perform as satisfactorily from the distortion viewpoint, particularly when present heat-treating equipment is unchanged. The problem is not insurmountable since developments in apparatus such as quenching fixtures, quenching media, grain size control, etc., have alleviated many of the difficulties with distortion.

Design Minimizes Distortion

Consideration of basic design to reduce warpage during quenching will demand more attention when the NE and lower alloyed steels are used. Sections must be more uniform and unsupported rims connected to webs must be increased both at the rim and the web to prevent "bowing" or a bell-shaped contour after quenching.

The type of heat treatment accorded a gear has a definite effect upon the final distortions. It is obvious that a direct quench for case-carburized steels or a prenormalized fully hardened steel produces the least distortion in their respective classes. The fine-grained NE steels are suitable for direct quench and will be required in lieu of double quenching where preference for minimum distortion outweighs core toughness. When production operations prevent a direct quench and maximum core toughness is required, the reheat quench temperature must be carefully investigated. For example, an increase of the

(Continued on Page 146)

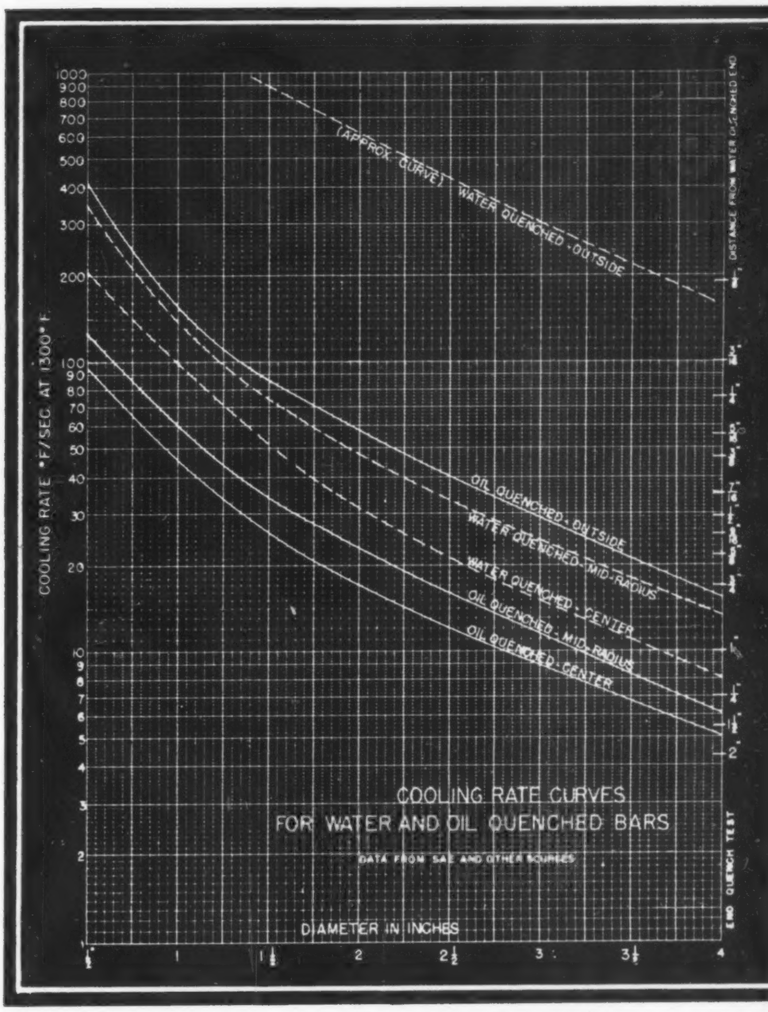
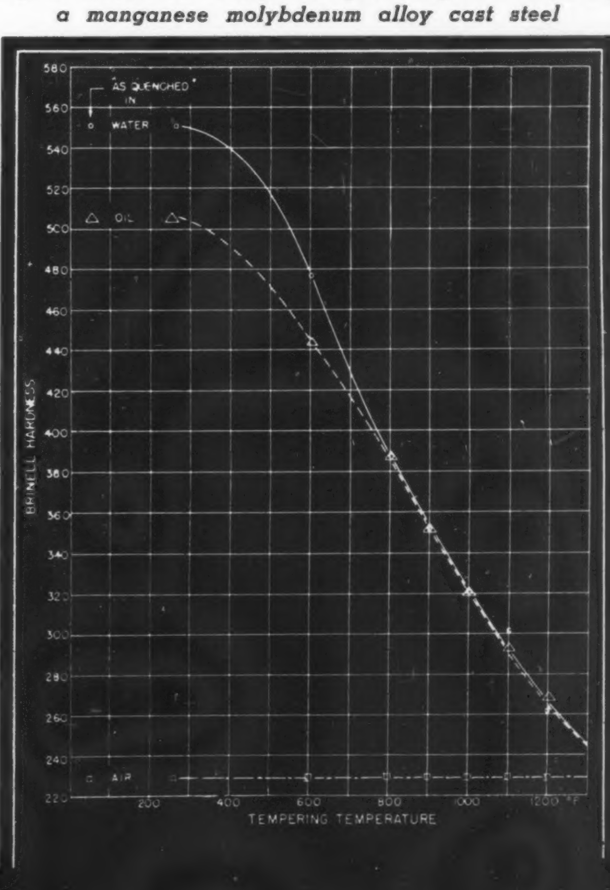


Fig. 8—Cooling rate curves for water and oil-quenched bars are utilized in correlating results of end quench test

Fig. 9—Effects on hardness of quenching and tempering a manganese molybdenum alloy cast steel



Code for Working Stresses F

Part I—Static Stresses

By Joseph Marin

Pennsylvania State College

IN THE DESIGN of machine parts there are many factors which determine the magnitude of the dimensions selected. The most important of these size-determining factors include: Operational and service requirements of the member; magnitude and character of loads acting on the part; and properties, availability and cost of the material used.

Modern developments in machine design are requiring a more rational estimate of these design factors. Increased speeds of operation, greater use of light-weight construction, and scarcity of materials demand a more accurate determination of dimensions. The important consideration of weight reduction in aircraft and many other constructions requires further accuracy in the selection of size.

The influence of service and operational requirements on the size of parts may sometimes be the governing consideration, while strength and other material properties become minor factors. On the other hand, loads and material properties may often be controlling factors. In some members the dimensions based on operational considerations can be changed in such a way as to effect a reduction in weight.

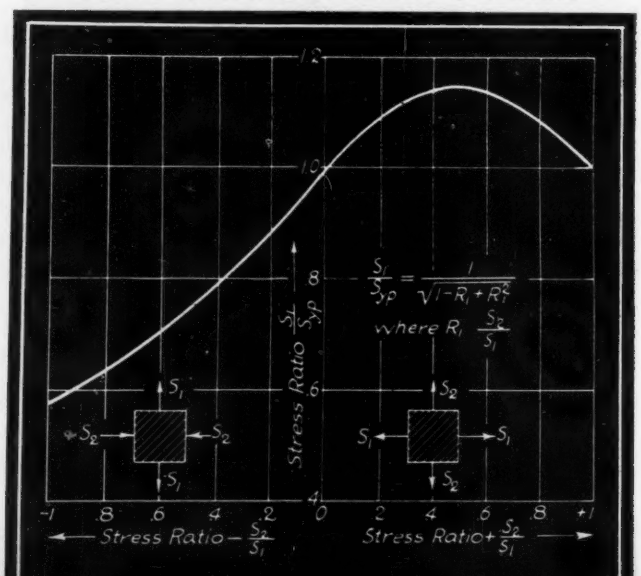
Influence of the load on size will depend upon the type, magnitude and accuracy of the stresses and deformations produced. Accuracy of stress determination is governed by the accuracy of the load and reliability of the stress analysis used. Precise load determination and stress analysis lead to a reduction in the factor of safety used and, hence, to a safer and more economical construction.

Selection of material also has become increasingly important. It is now necessary to consider available materials and to substitute new materials or ones previously not used. In many cases this change requires a more rational design since information on past performance is not available.

A thorough consideration of the properties of a material to be used for a particular machine part may involve many factors. A consideration of properties often may influence greatly the danger of failure, the economical use of the material, or the weight reduction. The required properties may include resistance to external effects, such as wear or corrosion, adaptability to a particular method of machining or fabrication, resistance to fatigue and high temperatures, etc.

Quantitatively, the mechanical properties of a material often determine the size of a member. Therefore stiffness, ductility, resilience, or strength may decide the dimensions selected. The governing mechanical property in many machine parts being strength, this article will be confined to working stresses based on the strength of

Fig. 1—Strength ratio for ductile materials and biaxial stresses for the stresses shown in the sketches



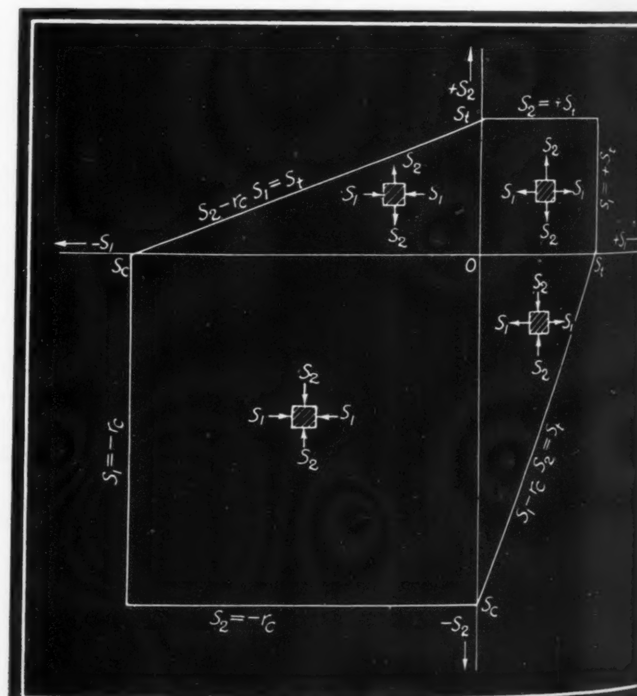


Fig. 2—Theory of failure for brittle materials and biaxial stresses. Stresses are shown in each quadrant

ates Design

materials. It should be noted, however, that the designer must also consider other load effects as, for example, the permissible angle of twist in a shaft or the allowable deflection of a beam. In the case of shock loads, resilience of a material is usually the governing property.

Restricting this discussion to the determination of the working stress based on the strength of a material, there are still many variables to consider. The working stress is

$$S_w=\frac{S}{N} \quad \text{(1)}$$

S_w is equal to the failure stress or strength S divided by the factor of safety N. In order to design both economically and safely it is necessary to select the working stress S_w as accurately as possible. This means that the values of the strength S and the factor of safety N must be evaluated as closely as possible. The purpose of this article is to deal with the selection of both S and N.

Selection of Factor of Safety

Selection of the factor of safety N involves many considerations. Past performance of a material or machine part must still play an important part in selection. It is important, however, to make as rational a determination of N as possible. For this purpose a separation of the various factors influencing N is desirable. If N_1, N_2, N_3, $--- N_n$ denote the quantitative value of each factor, then the overall factor of safety can be expressed by

$$N=N_1\times N_2\times N_3 --- \times N_n \quad \text{(2)}$$

A rational estimate, leading to a more accurate value of N, involves the following:

1. Material Factors N_1, N_2 and N_3: These consider the possible variation in the strength S as well as the differences between the laboratory test on which S is based and the service conditions. The possible variation in the strength depends upon the process of manufacture, the thoroughness of testing and inspection, and the character of the material itself. This possible nonuniformity can, however, be approximately predicted and a rational allowance for the factor of safety can be estimated. If the expected variation in strength is k_vS, the material factor N_1 is

$$N_1=\frac{S+k_vS}{S}=1+k_v \quad (a)$$

As considered later, the strength S may have various possible values depending upon the combinations of

Fig. 3—Piping and housings in turbo unit involve static stresses and creep—Courtesy Westinghouse E. & M. Co.

stress present and the type of loading applied. For fatigue stress conditions where flaws might be present, a large value of k_v should be used due to the progressive nature of fatigue failures.

The material factor N_2, which allows for the difference in behavior between the laboratory strength and the strength in the prototype, is a difficult one to estimate. If the strength S considers the type of load and the "combined stress effect", the factor N_2 may be modified. In machine design the weakest point in the member is considered and adjacent parts are not stressed to their maximum possible values. With ductile materials and static loads this condition prevents failure in many cases. For example, the yielding at a rivet hole under static conditions is not serious since a redistribution of stress with increase in stress values at the lower stressed points, and decrease in stress at the higher stressed points, is produced. If stress concentration is not considered in determining the strength an allowance must be made for this. This allowance can sometimes be based on laboratory tests. If the foregoing considerations are provided for by the factor k_c the material factor N_2 is

$$N_2=\frac{S+k_cS}{S}=1+k_c \quad (b)$$

A third material factor N_3 is applicable to static loads and ductile materials only. This value attempts to provide for the variation in the ratio of the yield tensile strength S_{yp} to the ultimate tensile strength S_u of ductile materials. An approximate method which allows for this is to introduce the factor N_3 as given by the equation

$$N_3=\frac{S_{yp}-(S_u-S_{yp})}{S_{yp}}=2-k_u \qquad (c)$$

where $k_u=S_u/S_{yp}$.

2. Load Factor N_4: The actual load on a machine or structural member will not be that assumed in a design since the magnitude, distribution and type of loading can usually be only roughly approximated. In many problems, however, an estimate can be made of the possible load variation from that assumed. In cases where impact loads are present an equivalent static load can be determined. Influences of possible variations in load distributions from those assumed can also be estimated. Stress variations corresponding to these possible load variations can then be found. If, for the critical point, this stress variation is $k_l S_w$ the factor N_4 is

$$N_4=\frac{S_w+k_l S_w}{S_w}=1+k_l \qquad (d)$$

where k_l is the stress variation due to the possible load changes divided by the working stress.

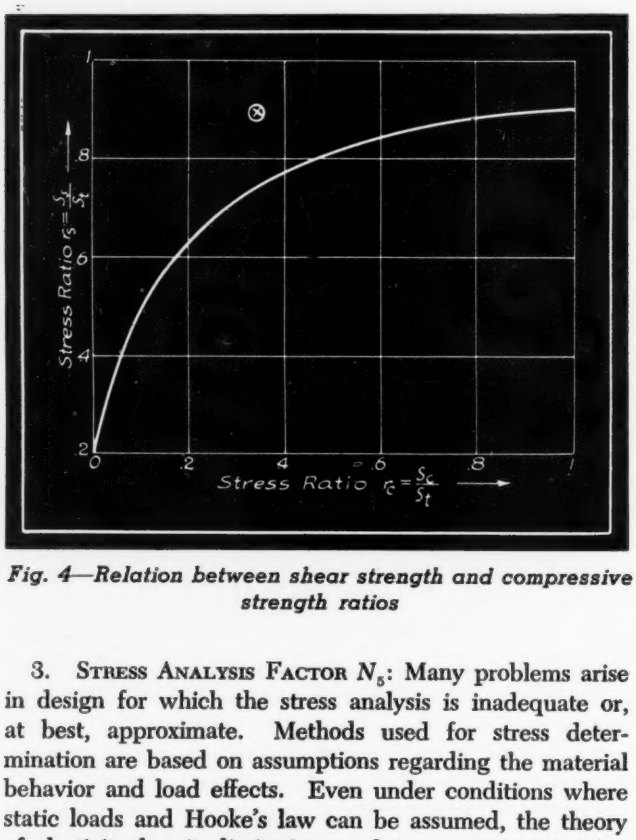


Fig. 4—Relation between shear strength and compressive strength ratios

3. Stress Analysis Factor N_5: Many problems arise in design for which the stress analysis is inadequate or, at best, approximate. Methods used for stress determination are based on assumptions regarding the material behavior and load effects. Even under conditions where static loads and Hooke's law can be assumed, the theory of elasticity has its limitations and an approximate stress value is determined. When conditions of vibration or instability occur, with possible failure by buckling, the designer must either analyze these effects or provide for them in the factor of safety. In many problems the stress analysis factor of safety N_5 can be obtained accurately by improving the method of stress analysis used. This is done either by using a more accurate theory such as the theory of elasticity or an experimental method of stress analysis. The photoelastic, strain rosette, and stress-coat methods have been of great help in this respect[1]. In a particular design, if the percentage error in stress, based on an experimental or improved theoretical method, is 100 k_a, the stress analysis factor becomes

$$N_5=\frac{S+k_a S}{S}=1+k_a \qquad (e)$$

1. All references are listed at end of article.

4. Fabrication Factor N_6: For machine parts in which tolerances in dimensions are provided for—and also where this is not the case—the resulting dimensions are not those assumed in determining the stress. The error can be taken care of by selecting an appropriate fabrication factor. More important than these variations in dimensions are the changes in the properties of the material and the initial stresses sometimes produced by the method of fabrication adopted. Operations such as punching of plates for rivets or the bending and hammering of parts into a required shape weaken the material and introduce initial stresses. Sometimes the heat treatment applied to the test specimen has a different effect than when the same treatment is applied to the larger machine part. In large welded constructions, as in ships where stress relieving cannot be applied, high shrinkage stresses occur. In some instances the effects of fabrication methods can be controlled and the influences estimated with reasonable accuracy. If the fabrication factor is k_f, the fabrication factor of safety N_6 becomes

$$N_6=\frac{S_w+k_f S_w}{S_w}=1+k_f \qquad (f)$$

Value of N_6 is based on the working stress S_w since the value of k_f can best be determined based on this stress.

5. Time Factor N_7: This factor includes the influence of external conditions in modifying the material properties. Deterioration of a material with time as, for example, the corrosion of steel or decay of wood by moisture will modify the factor of safety used. In this respect the estimated life of the machine and provision for maintenance will greatly influence the value of the time factor N_7. Another time factor which is sometimes provided for in the determination of S is the influence of creep at both normal and elevated temperatures. Creep, which is a continued plastic deformation with time, occurs in lead and other alloys at normal temperatures. At elevated temperatures, as found in equipment used in the oil refining, turbine and automotive industries, creep has an important influence in the selection of working stresses. Some data to evaluate the time factor N_7 can be obtained based on service conditions and mechanical tests made on parts which have been in operation for a number of years. Laboratory tests have been useful in some problems in estimating the influence of time effects on strength. Many such studies have been made as, for example, the influence of corrosion on the fatigue strength of steel. Based on the foregoing consideration, a time factor N_7 will be selected in terms of the correction factor k_t where

$$N_7=\frac{S+k_t S}{S}=1+k_t \qquad (g)$$

6. Failure Factor N_8: In determining the factor of safety, the consequences in the event of failure are

an extremely important consideration. If failure would result in loss of life a higher factor of safety should naturally be used. When failure would result in loss of valuable property or serious interruption of production processes an ample factor of safety should be provided. If, on the other hand, only the operation of an inexpensive machine part is temporarily interrupted, the failure factor k_e can be small. Sometimes certain precautions can be taken to eliminate serious consequences if failure occurs. Spiral-steel reinforcement in concrete columns is an example of this kind of insurance against a disastrous type of failure. For ductile materials and static loads, yielding accompanied by redistribution of stresses also gives an insurance against serious failure.

In many machines it will be necessary to determine the failure factor of safety N_8 largely from the information available on previous failures and from experience with similar constructions. In any event, the factor becomes

$$N_8 = \frac{S_w + k_e S_w}{S_w} = 1 + k_e \quad \text{.............................} (h)$$

There may be other factors which are encountered in special cases—factors not included in the above discussion. For these situations the factor N_8 can be modified to provide for unusual conditions.

An inspection of the foregoing discussion shows that the resultant factor of safety N becomes

$$N = N_1 \times N_2 \times N_3 \times N_4 \times N_5 \times N_6 \times N_7 \times N_8 \quad \text{...........} (2a)$$

Substituting values of N_1 to N_8 from Equations *a* to *h* in Equation *2a*,

$$N = (1+k_v)(1+k_c)(2-k_u)(1+k_l)(1+k_a)(1+k_f)(1+k_t)(1+k_e) \quad \text{.................................} (3)$$

where

k_v = material variation factor
k_c = material stress factor
k_u = ratio of ultimate strength to yield strength in static tension
k_l = load variation factor
k_a = stress analysis factor
k_f = fabrication factor
k_t = time factor and
k_e = failure factor

There will, of course, still be a number of uncertainties in determining the factor of safety by using an equation similar to Equation 3. A rational method has been outlined, however, which should lead to a more accurate value. Separation of the many considerations influencing the factor of safety has been made in a simple manner so that a more intelligent estimate of each can be provided.

Importance of estimating the factor of safety as accurately as possible cannot be overemphasized. The other quantity which must also be known before the working stress can be determined is the strength of the material designated by S in Equation 1. This strength will be the yield strength for ductile materials subject to static loads, or the ultimate strength in the case of brittle materials subject to static loads. For fluctuating stress conditions, the strength is dependent not only on the static yield or ultimate strength but also on the endurance limit of the material for complete stress reversal. The stress S is then defined as an equivalent static tensile stress. For problems in which a combined state of stress occurs it will be necessary to modify the strength value S to provide for the influence of the combined stresses on the strength of the material. For this purpose an equivalent simple static stress S can be obtained for either static and fatigue stresses. Provision for these combined stresses is outlined in the following code for working stresses.

Previous articles of this series have shown how the combined stresses have influenced specific machine design problems. Another consideration that will now be incorporated is an allowance for stress concentration. The discussion will be confined to static and fatigue stresses only. Impact conditions will be excluded since the information available on resistance under impact is meager and because resilience, rather than strength, is often the governing property for impact loads. High and low-temperature stress conditions will be excluded also since these situations are encountered only in special machine design problems.

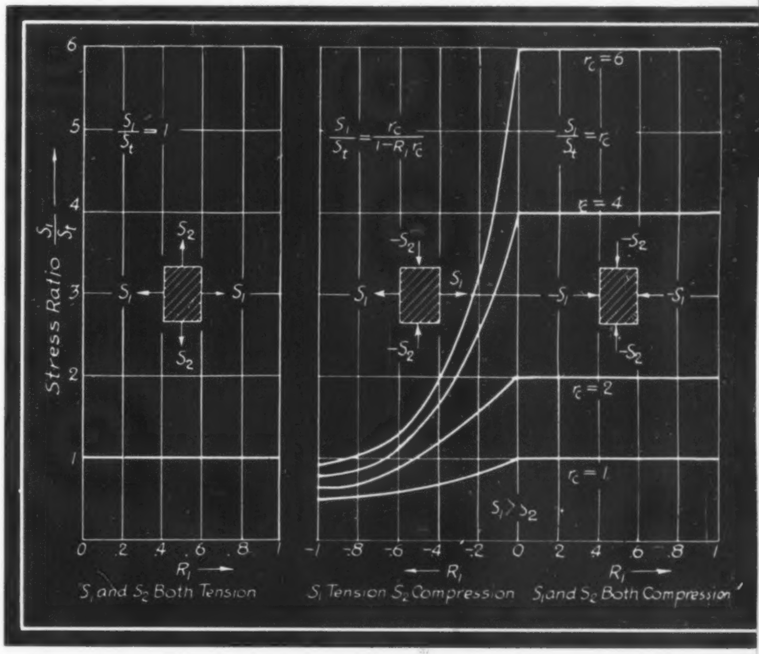


Fig. 5—Strength for brittle materials and biaxial stresses

Static Stresses

Development of the theories of failure used in the following will be omitted, with only references being given as to where the development of the theory can be found[2]. For the purpose of defining strength, materials will be classified into two groups: *Ductile materials* having an elongation in simple tension of more than five per cent, and *brittle materials* having an elongation of less than five per cent[3]. The strength of ductile materials will be defined by the yield strength S_{yp} based on the lower yield point where one exists or on the A.S.T.M. offset yield strength[4] where a pronounced yield point does not exist. For many ductile materials the yield strengths in tension and compression can be assumed equal. On the other hand, for brittle materials the strength must be defined

by the ultimate strength and the values of the strength in tension and compression may be appreciably different. For purposes of classification, stresses will be divided into uniaxial, biaxial and triaxial stresses, as discussed in the following:

Uniaxial Stresses — Ductile Materials: Strength in compression can usually be assumed equal to that in tension. The strength is based on the yield strength S_{yp}, as previously explained. That is,

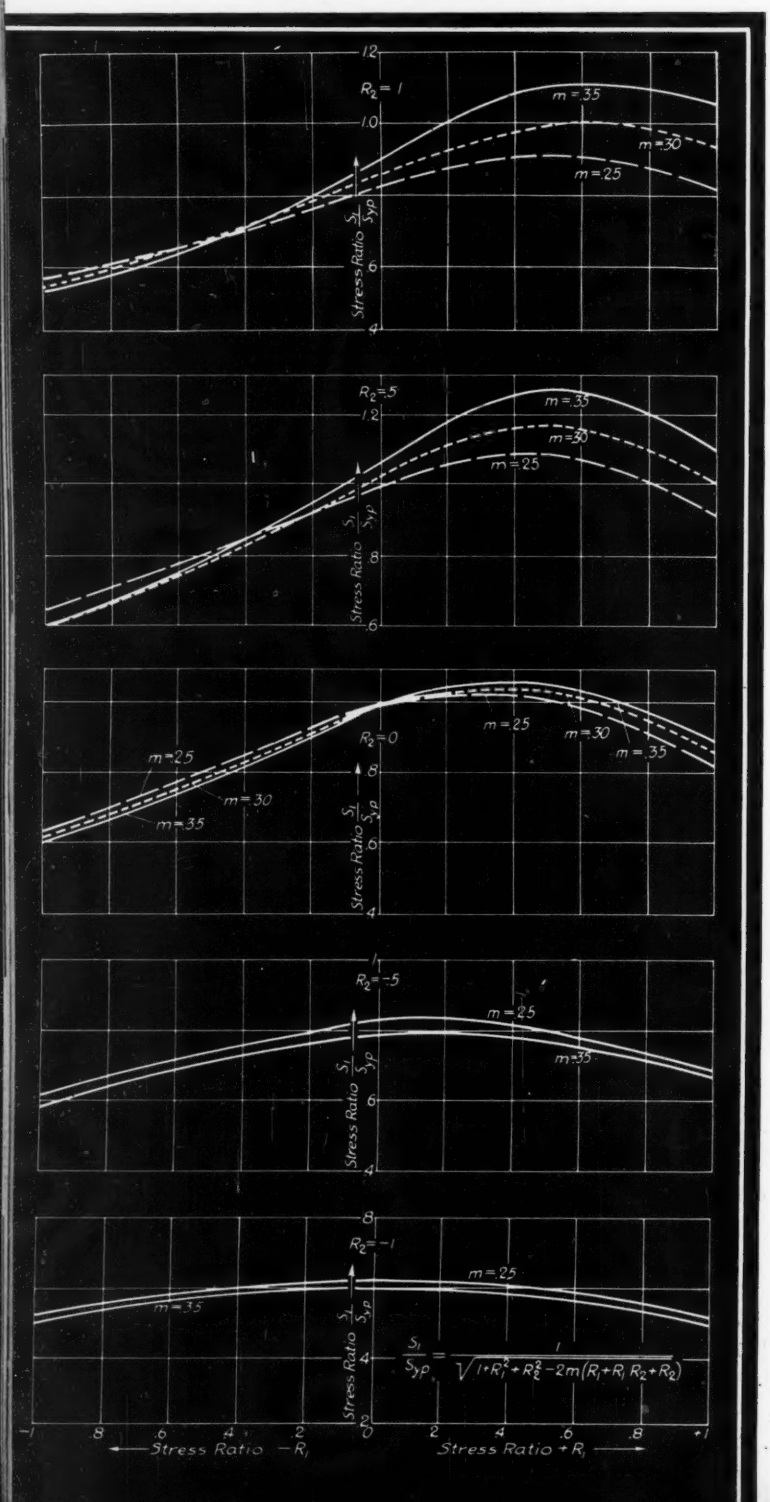
$$S = \pm S_{yp} \qquad (4)$$

Uniaxial Stresses—Brittle Materials: For materials with an elongation less than five per cent, the ultimate stress defines the strength. If the ultimate strength in tension is S_t and in compression S_c, the strengths are, respectively,

$$S = +K_t S_t \text{ and } S = -K_c S_c \qquad (5)$$

where K_t and K_c are stress concentration factors in tension and compression respectively. Values of stress concentration factors for some types of fillets and certain simple stress problems have been obtained and are compiled by Roark[5].

Fig. 6—Strength ratios for ductile materials and triaxial stresses for various values of R2



Biaxial Stresses—Ductile Materials: For ductile materials subject to biaxial principal stresses S_1 and S_2, failure will be defined by the distortion-energy theory[2]. Many designers still use the shear theory and argue that this is easier to apply. Application of the distortion-energy theory to the foregoing series shows that there is little choice in this respect. Since the experimental evidence definitely favors the distortion-energy theory for biaxial stresses it seems to the writer that this theory should be used. The relation between the principal stresses S_1 and S_2 by the distortion energy theory is

$$S_{yp}^2 = S_1^2 - S_1 S_2 + S_2^2 \qquad (6)$$

To represent the influence of the combined stresses, considering that S_1 is the greatest principal stress, Equation 6 becomes

$$\frac{S_1}{S_{yp}} = \pm \frac{1}{\sqrt{1 - R_1 + R_1^2}} \qquad (6a)$$

where $R_1 = S_2/S_1$ and $S_2 < S_1$.

Variation in the stress ratio S_1/S_{yp} with change in the stress ratio $R_1 = S_2/S_1$ is shown in *Fig.* 1. This figure can now be used to select the equivalent strength S_1 for any stress ratio R_1.

If the stress components are expressed in terms of the normal stress S_x and S_y and a shear stress S_{xy} in place of the principal stresses S_1 and S_2, Equation 6 then becomes

$$S_{yp}^2 = S_x^2 - S_x S_y + S_y^2 + 3S_{xy}^2 \qquad (6b)$$

Biaxial Stresses—Brittle Materials: For brittle materials such as cast iron, which are subject to biaxial stresses, there is little experimental data upon which to base strength values. It is highly desirable to provide at least for the difference which exists between the tensile and compressive strengths of most brittle materials. For this purpose the internal friction theory or a special case of Mohr's theory is recommended.[2] This theory is defined by the following equations where $S_1 > S_2$ and is represented graphically in *Fig.* 2.

For principal stresses of the same sign,

$$S_1 = -S_c \text{ or } S_1 = S_t \qquad (7a)$$

For principal stresses of opposite signs,

$$S_1 - r_c S_2 = S_c \qquad (7b)$$

where $r_c = S_c/S_t$.

For the case of pure torsion, Equation 7*b* can be used

(*Continued on Page* 158)

Cold-Molded PLASTICS

By J. Delmonte
Technical Director
Plastics Industries Technical Institute

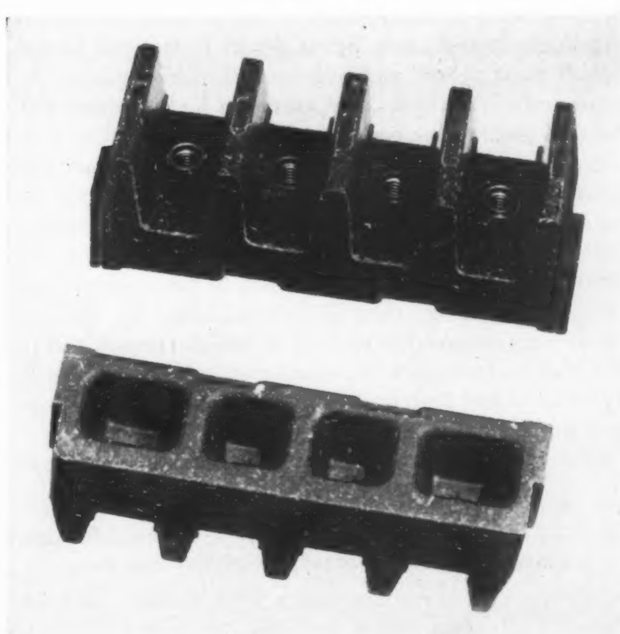
Fig. 1—Above—Nonrefactory types of cold-molded plastics. Photo courtesy American Insulator Corp.

CURRENT demands for plastic materials in the war program make it imperative that every possible source of material supply be examined and applied if practical. Increasing attention is being given to cold-molded plastic materials, because they possess characteristics which in some respects make them competitive with hot-molded varieties. Cold-molded materials are not new by any means; they enjoyed a period of widespread industrial applications before synthetic resins reached their full stride. Being available only in dark shades, however, the cold-molded materials fell into the background as industry became color conscious. Today, color in many cases is of secondary importance and the cold-molded plastics should be examined on the merits of their physical and electrical characteristics and ease of reproducibility.

One important factor which will mitigate against an extensive adoption by all molders is that the materials are not generally sold by materials producers to custom molders, as is the practice for phenolics, ureas, cellulose derivatives, vinyls, acrylics, etc. In general, companies producing cold-molded parts are limited as to number and to producing for their own particular requirements. Nevertheless, the fact that the raw materials are abundant and available at low cost should not be overlooked.

In its correct interpretation cold molding refers to the art of compressing moldable compositions in a steel mold and baking these parts afterwards, converting them to hard, mechanically suitable pieces. In recent years its definition has been broadened to encompass those materials which fall between the limits of cold molding (at room temperatures) and hot molding (in a range of 290-360 degrees Fahr.). Consequently the term semihot molding might be used, though because of resemblance of the raw materials this group might be included in the cold molding category.

Fig. 2—Below—Terminal strips and similar connectors utilize cold-molded plastics. Photo Courtesy Cutler-Hammer Inc.



Cold-molded materials are generally classified as one of the following groups:

1. Nonrefractory
2. Refractory

The second classification includes materials which are more correctly classified as ceramics rather than plastics, largely because of their inorganic origin and high firing temperature at the time of manufacture. Numerous binders

have been employed in these compositions including various hydraulic cements in combination with asbestos filler, silica-lime cements, and magnesia compounds, notably the double silicate of alumina and magnesia.

Nonrefractory compounds employ as binders various asphalts or hard bitumen, natural or oil derivatives, coal tar pitches, stearine pitches, oxidized oils, and a number of gums and resins. Best known among these binders are bitumen and stearine pitch in combination with drying oils. These are wet blended usually in presence of infusorial earth, silica, magnesia compounds, and asbestos. For low temperature applications cotton flock fillers are sometimes employed.

When the mixture has been thoroughly blended it must be in such a plastic condition as to be moldable in closed molds to the required shape and form. If too dry it would be difficult to mold or liable to produce porous bodies. If too plastic or too soft on the other hand, there would be difficulty in removing the piece intact from the mold. As an aid to flow, refractory types may be semiwet during molding, while a small amount of heat or synthetic phenol-formaldehyde resin may be employed to improve flow of asphalt bases as well as appearance of molded parts.

TABLE I

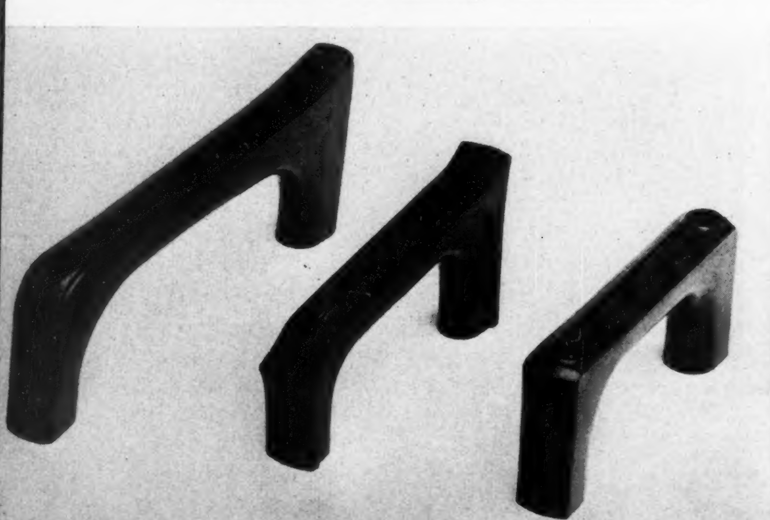
Comparison of Hot Molding and Cold Molding Processes

	Hot Molding	Cold Molding
Molding pressures (psi)	1,000 to 5,000	Up to 10,000
Temperature of mold (F)	290-360	Under 200
Time of molding cycles (sec)	90 to 900	5 to 15
Accuracy of molded parts	Excellent	Fair to Poor
Physical characteristics	Excellent	Fair
Electrical characteristics	Excellent	Excellent
Temperature resistance	Fair	Excellent

Generally, the rapid development of high pressure suits the cold molding process, which is completed in as short a time as possible. Mechanically actuated rather than hydraulic presses may be preferred for this reason. The material is somewhat abrasive in character so that molding dies are short lived as compared with hot molding. The average cold molding die is returned to the machine shop for repairs after less than 50,000 moldings. For this reason dies are designed in sections to facilitate repair and replacement. Designers of cold-molded parts should not be surprised to find flash lines at somewhat unexpected places on completed pieces.

General comparisons of hot and cold molding operations appear in TABLE I. In a typical semihot molding process such as may be practiced in production of a storage battery container, the asphalt, kieselguhr, and cotton flock may be hot blended together in required proportions and then placed in a mold at temperature of 190 to 200 degrees Fahr. The material is preferably preheated to shorten the molding cycle. As the mold commences to close, the charge flows out, reproducing details of the design. Cold water circulates through the mold to chill and set the somewhat thermoplastic material. After removal from the mold, the part requires no further baking. Such composition cases are more in demand now than before because of unavailability of hard rubber. Prior to the war about 75 per cent of storage battery cases in this country were produced from cold or semihot molded asphaltic compositions. Also of interest is the fact that continuous extrusion of refractory type insulation has been found practical for several years.

Fig. 3—Attractive handles are nonrefractory cold-molded plastics. Photo courtesy Cutler-Hammer Inc.



Where parts are cold pressed alone, baking is an important factor. To obtain efficient production, many parts are handled at one time. Baking drives off volatile matter and then oxidizes and polymerizes the oils and binders so that the material will become hard. This is not accomplished easily because warpage and shrinkage problems are incurred. Proper racking of parts during baking requires much experience. At least 24 hours is required in baking over a gradual temperature rise.

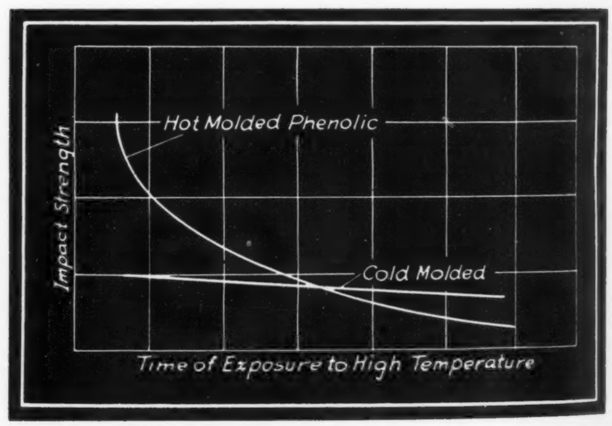


Fig. 4—Effect of exposure upon impact strength compared with phenolics

While the general principles of designing cold-molded parts follows conventional practice for hot-molded thermosetting plastics, the following design features should be noted in particular:

1. TOLERANCES: Vertical tolerances in the same direction as the application of molding pressure should be liberal. Fairly shallow pieces such as plugs or panels may have tolerances of plus or minus 1/64-inch on their thickness. Dimensions lying perpendicular to direction of molding pressure may be specified at about plus or minus .008-inch per inch.

2. DRAFT: Preferably a minimum draft of three degrees should be specified in designing all cold molded parts, though this depends to a large measure on the depth of the article. The material is rather weak at the time of ejection from the mold and design features which will aid in its safe removal should be incorporated. For sections

greater than $1\frac{1}{2}$ inches in depth, a draft angle of five degrees may be necessary.

3. Curves and Radii: The strength and serviceability of cold-molded articles are much dependent upon well-rounded and well-curved surfaces. As a design rule a minimum radius of $\frac{1}{8}$-inch should appear on cold-molded parts, except of course at those planes constituting mold parting lines. Exterior surfaces and corners should have generous radii of at least $\frac{1}{4}$-inch, improving not only resistance to chipping and breakage, but also appearance. It must be remembered also that sharp corners are short lived in cold molding dies, the composition rapidly wearing these down by its abrasive action.

4. Holes: Through holes or partly cored holes perpendicular to direction of molding are satisfactory providing they too are designed with ample draft. Side or oblique holes should be avoided, except in the cases of semihot molding where there is sufficient flow in the material to avoid damage to the coring pins. In the final molded parts, holes are first molded according to the maximum permissible diameter and then as pins wear down the hole size becomes smaller. When lowest tolerance limit is reached the pins are replaced in mold.

5. Inserts: Metal inserts should not be molded in position. Holes for locating them may be molded and then inserts pressed into place. A straight knurl on the insert is specified under these conditions.

6. Finish: A dull, smooth finish may be expected of most cold-molded parts, not glossy like hot-molded phenolics. Contrasting surface effects may be realized by the introduction of special knurls or stipple effects on the exterior. These will break up the monotony of dull black and will improve appearance.

7. Wall Thickness: A minimum of $\frac{1}{8}$-inch is recommended. Cold-molded parts are generally heavier than hot-molded pieces. Because material does not flow much during molding, the design should attempt to keep wall thickness uniform.

Representative properties appear in Table II. Cold-molded bitumen base materials are appreciably weaker than hot-molded phenolics which may have, for example, tensile strengths of 8000 to 9000 pounds per square inch. However, in many cases the strength of cold-molded materials is adequate and in view of their lower cost and greater availability they may make the better choice. Physical properties are less affected by temperature. For example, *Fig.* 1 shows the variation of impact strength upon prolonged exposure to a temperature around 400 degrees Fahr. Phenolics may have an initial advantage, though cold-molded parts are superior after continued service.

At present cold-molded plastics are best known for their applications to electrical equipment, representative examples of which appear in the accompanying illustrations. Much more satisfactory than phenolics in the presence of power arcs, they show little or no tendency to carbonize as do the phenolics. Consequently there are numerous examples of asphalt base plastics to switches, circuit breakers, arc chutes, etc.

Refractory types are, of course, well suited to high temperature applications. Good dielectric properties at varying temperatures and humidities can be expected. When

Fig. 5—Intricate moldings of both refractory and nonrefractory cold-molded plastics are useful for electrical equipment. Photo courtesy General Electric Co.

designing, ample allowance should be made for changes in thermal expansion and contraction between different materials. Slotted cores for attachment rather than accurate diameter holes may be a wise procedure.

In recent months some manufacturers have reported switching to cold-molded plastics with little or no difficulty. For example, a manufacturer turned to a cold-molded plastic for a small portable motor housing, formerly phenolic, with little or no difficulty.

While some manufacturers will find that cold-molded plastics enable them to maintain the goodwill of customers not engaged strictly in defense production, there are more important applications to consider. For example, much phenolic is being utilized for various caps, covers, en-

Table II

Properties of Cold Molded Parts

	Typical Asphalt Base-Asbestos Filler	Typical Hydraulic Cement Asbestos Filler
Specific gravity	2.00	1.90
Tensile strength (psi)	1500- 2000	Low
Compressive strength (psi)	5000-13,000	15,000
Flexural strength (psi)	5500	4500
Dielectric strength (v/mil)	50- 100	40-80
Water absorption (%/24 hr.)	.6-7.5	.5-26
Heat Resistance (C)	250	1000

closures and other ordnance equipment where the sole function of the plastic is to save metal. Physical requirements are somewhat minor in these instances. It would appear more prudent to employ the cheaper, more abundant cold-molded materials, saving the somewhat critical phenolics for more vital measures.

It is doubtful that the material is strong enough for machine applications such as gears and bearings, but it should certainly be considered for bushings, guides, small brackets, etc. In designing a part it is well to apply the stress over as large an area as possible, rather than through a single keyway, as for example when placed on a shaft. This will insure better mechanical suitability. Most important in new uses for these old materials is to recognize their possibilities. When the correct design conditions prevail, cold-molded plastics will do their share in the war effort.

War Theme Dominates Metal Show

WHAT may prove to be the last national metal congress and exposition for the duration was held in Cleveland last month, attracting thousands of officials, executives and technical experts. The wide variety of exhibits, all related more or less directly to the war program, bore witness to the extent of the metals industry's all-out participation in the war. Most of the machinery and equipment exhibited at the show was en route to war plants for delivery immediately after the show closed.

With the materials shortage a leading problem, considerable interest centered on such exhibits as those showing alternatives for rubber, substitution of steel for brass shell cases, surface protection of metals for longer life, etc. From the production standpoint were displayed new welding machines, special machine tools, heat-treating furnaces, and freezing equipment for metal conditioning and storage to prevent age-hardening.

Importance of maintaining quality along with greatly increased production was underlined by the presence at the show of numerous inspection devices, particularly X-ray radiographic equipment and magnetic tests for detecting flaws.

Of interest to designers was the exhibit by the United States army ordnance department, showing how spectacular savings of materials and machine-hours are being attained through redesign of small parts required in enormous quantities. Ingenious use of brazed stampings in place of solid parts made on automatic screw machines is largely responsible for these savings. As a typical example may be cited a fin locknut which, with the redesign, saves 100,000 machine-hours and enough steel for 11,500 Garand rifles on an order for 2,000,000 nuts, with an incidental saving of $283,000.

Stresses War Production Problems

A leading attraction of the technical program held in conjunction with the show was the series of twenty-three war production sessions at which outstanding authorities spoke briefly and off the record on such vital topics as NE steels, personnel training, repair and salvage of tool steels, interpretation of inspection tests, selection of tool and die steels for mass production, powder metals, production heat treatment, tin conservation, and surface protection. The group of speakers at each session also acted as an information panel for open discussion, and much information of value to the war program was exchanged.

Where Shaded-Pole Motors Fit

By John W. Greve

SHADED-POLE motors have definite applications for which their particular characteristics are advantageous in the war program. Seldom applied to drives requiring more than 1/20-horsepower because of low efficiency and associated high losses with resultant heating, this type of motor is used chiefly for timing devices, fans, etc., where the starting torques are low.

Inherent low efficiency is not an important factor where these motors are commonly used. Because of their small size and the small amount of power delivered, the current drawn in any event is usually low and does not reflect any great expense in operating cost.

Outstanding advantages of these motors include low cost resulting from simplicity of construction, minimum maintenance because of absence of wearing parts such as brushes and centrifugal switches, ability to withstand locked-rotor conditions without damage, quiet operation obtained from the simple construction and favorable magnetic conditions, low starting current, relatively constant speed and compact design.

Compact Design Is Valuable

Typical present day applications include fan drives for carbon monoxide detectors on submarines and radio transmitters for Signal Corps; film changer drives for stereoscopic X-ray machines; and drives for various types of timers for laundry equipment, air raid sirens, etc. In many applications of this type space is restricted so that the compact construction of shaded-pole motors is particularly valuable.

Operation of shaded-pole motors is analagous to that of 2-phase induction motors because an out-of-phase or lagging field is induced on one side of each salient pole by an auxiliary winding or stamping. Definition by the American Standards association is: "A shaded-pole motor is a single-phase induction motor provided with an uninsulated and permanently short-circuited auxiliary winding, displaced in a magnetic position from the main winding."

To illustrate the characteristic features, a cross section of a typical four-pole motor is shown in *Fig. 2*. Construction in this case is such that the field coils may be slipped over the poles. The shading

Fig. 1 — Above — Parts comprising a shaded-pole gearmotor. This design delivers only one revolution per hour

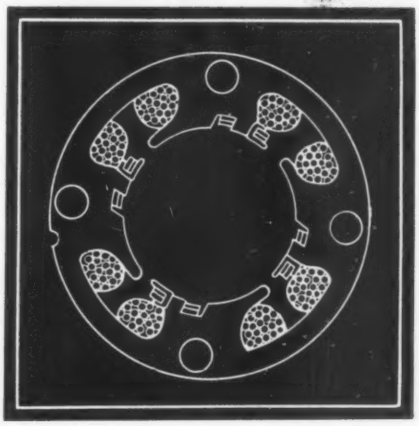


Fig. 2—Right—Cross section of a typical shaded-pole motor showing main coils and shading coils

coils are punched washers and fit over the short tips of each pole to form a starting winding. The gap between the poles is partially closed to improve performance.

Direction of rotation is always toward the shading coil. Reversing features may be incorporated in three ways. One is to have a second set of shading coils on the opposite side of each pole with their terminals so arranged that either set may be short-circuited depending on the direction of rotation desired. Another is to have two sets of main windings, The third utilizes distributed main windings tapped 90 degrees apart so that reversing connections of opposite taps will reverse the motor. This third arrangement has the advantage that all of the windings are utilized to give somewhat better performance.

Speed is preferably varied by the use of a choke coil connected in series with the primary winding although an external resistor can also be used. The speed is relatively constant varying with the load but being independent of voltage fluctuations within limits. Always below synchronous speed, a shaded-pole motor does not "run away"

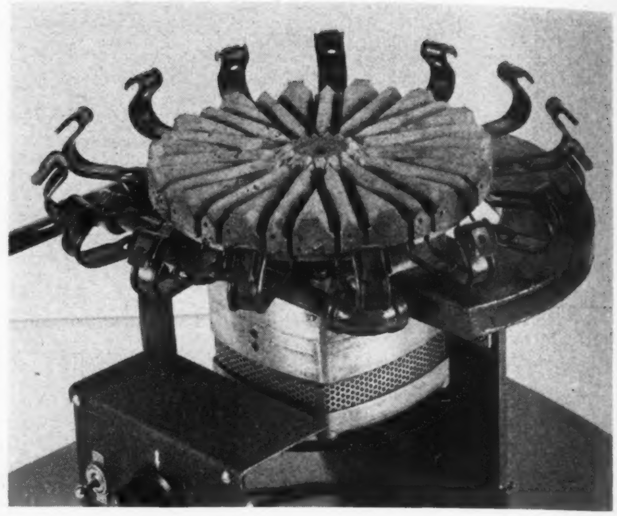


Fig. 5—Furnace for heat treating small parts employs a shaded-pole motor to drive at relatively constant speed

like a series motor. Two-pole motors generally run about 3000 revolutions per minute, the slip being controlled by design features. Four-pole motors develop about 1600 revolutions per minute.

Shaded-pole motors are usually operated close to their maximum torque because efficiency is best at that point. In fact the locked-rotor input is only about 40 per cent above full-load current. That is the reason this type of motor is not readily damaged when stalled.

Starting torques are unusually low but can be controlled somewhat in the design of the motor. To increase the starting torque requires higher slip and sacrifice of other motor characteristics. Typical curves for a 1/400-horsepower four-pole motor of the type illustrated in *Fig.* 2 are shown in *Fig.* 3.

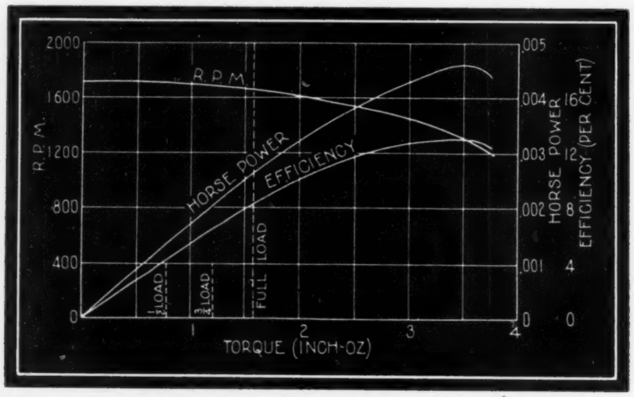
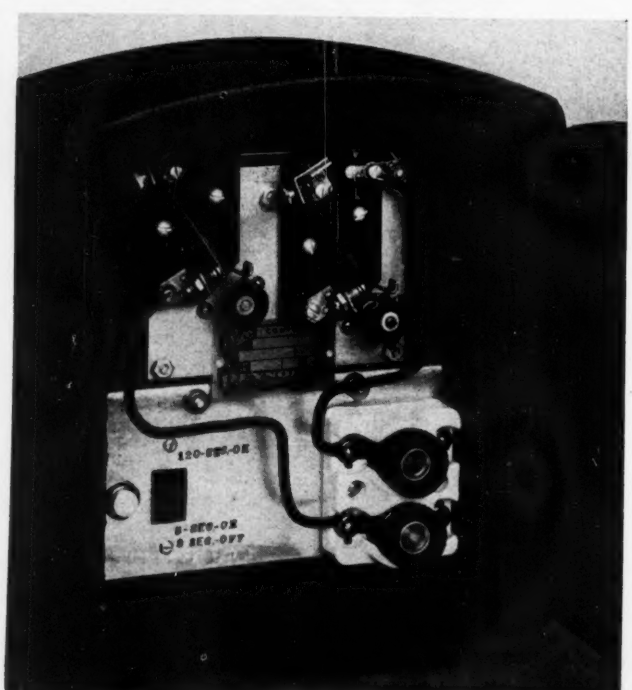


Fig. 3—Characteristic curves for a 1/400-horsepower shaded-pole motor

Fig. 4—Below—Air raid alarm control utilizes disk-type shaded-pole motor for timing cycle



Gearhead Types Are Widely Utilized

A large percentage of shaded-pole motors have built-in reducers to produce almost any speed desired as low as one revolution per week. These are useful for timers for various sequence control applications. In *Fig.* 1 is a disassembled view of a geared-head, synchronous shaded-pole, hysteresis motor delivering 1/60-revolution per minute on 60-cycle current. The motor has a speed of 450 and will develop torques beyond the capacity of the gearing which is 20 inch-ounces. Particularly compact because of its shaded-pole design, the entire assembly, exclusive of driveshaft, is less than 2½ by 2¼ by 1¼ inches.

Copper shading rings on this motor shade the eight motor field poles. To make such a motor self starting by any other means would add tremendously to the size and also to the cost of manufacture. These motors have a variety of applications to equipment such as recording instruments, contactors, interrupters, automatic reset timers, protective relays and other timing units having high priority ratings for Army, Navy and Signal Corps applications.

The air raid alarm control shown in *Fig.* 4 utilizes a disk type shaded-pole motor to supply signal alarms in 15 cycles during 120 seconds and a steady "all clear" siren blast for 120 cycles. Cam-operated silver contacts supply the impulses. The unit is mounted in a weather-

proof cabinet with fuse block and pushbutton.

Interesting from the point of view of a compact drive requiring small power is the oven shown in *Fig.* 5, used for tempering small machine parts. The motor is required to maintain a constant speed. This is satisfactorily accomplished because the loading is uniform for each particular batch.

Typical of applications to cycle controls for dry cleaning units and laundry equipment is the unit shown in *Fig.* 6. This drive utilizes a worm-gearhead to provide the low speed required for the cycle. In controls of this kind, extreme accuracy of timing such as provided by synchronous motors is not justified. Repetitive cycles of approximately equal intervals is all that is necessary. Because the loading on the control is uniform, relatively constant rates are obtained.

In *Fig.* 7 is a motor-driven eraser of the type used in engineering departments. Being compact and simple, the shaded-pole motor with a gear reduction supplies adequate power to drive the revolving head. Motor was selected because it comes up to speed quickly, consequently the eraser is ready for use as soon as it is picked up. Control is by a mercury switch installed in the housing to close the circuit as soon as the instrument is brought into the erasing position.

Micrometer Has Reversing Motor

A reversing, shaded-pole motor is applied to the electronic micrometer in *Fig.* 8. It was selected in this case because it is possible to control the direction of rotation from electronic tubes, allowing the measurement of resilient materials as well as metals. The motor direction is reversed when contact with the materials being measured is made. In this way pressure on the part being measured is eliminated.

Fig. 6—Below—Sequence timer for dry cleaning unit is driven by worm-gearhead motor

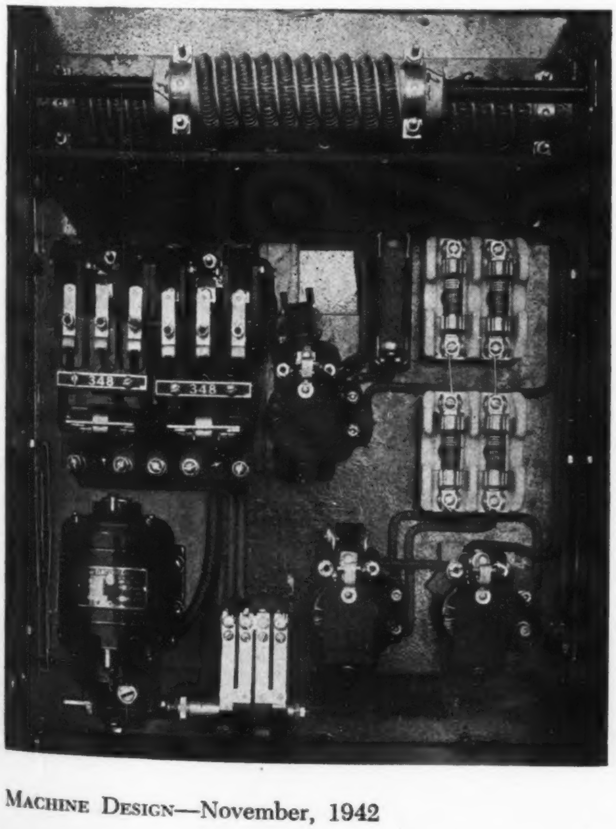
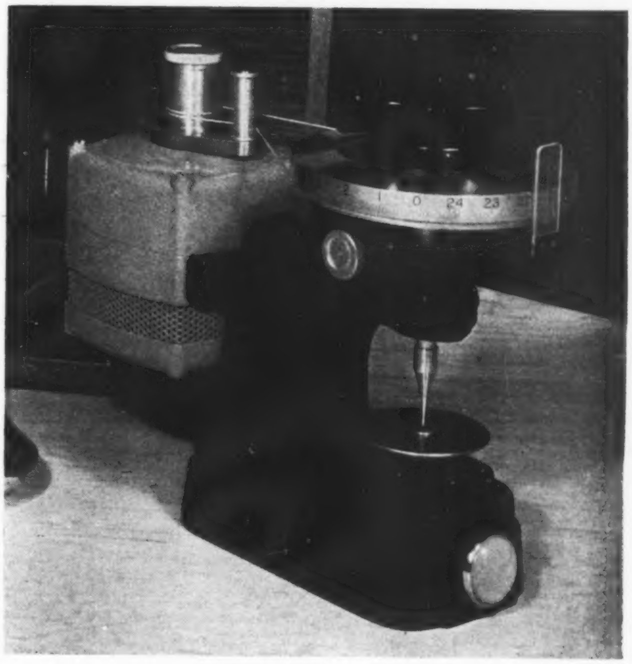


Fig. 7—Right—Compact motor - driven eraser is ready for use when picked up. Mercury switch in housing operates unit

Fig. 8 — Below — Reversible shaded-pole motor is controlled by electronic tubes



Shaded-pole motors have also been applied successfully to flexible shaft tools. In spite of the fact that they run at about half the speed of series-wound motors, the torque developed is sufficient for the application. Another use is for revolving the anodes in an electroplating operation. In this case it is necessary that the motors continue operating. The loss of many valuable parts would be suffered if the electrode were to remain still, and the plated articles were to burn.

Assistance in the preparation of this article from the Bodine Electric Co. is gratefully acknowledged as is also their courtesy in supplying *Figs.* 2, 3, and 6. Other companies co-operating by supplying data and application photographs include Barber Colman Co., *Figs.* 5, 7 and 8; General Electric Co.; Haydon Mfg. Co., *Fig.* 1; Reynolds Electric Co., *Fig.* 4; F. A. Smith Mfg. Co., Inc.; and Speedway Mfg. Co.

LOW-Cost phenolic plastics utilizing cottonseed hull fillers have been developed at the University of Tennessee to utilize a material which had heretofore been used as roughage for cattle. Less expensive than wood flour, cottonseed hulls give certain desirable properties to plastics among which is a degree of elasticity under stress not shared by other materials.

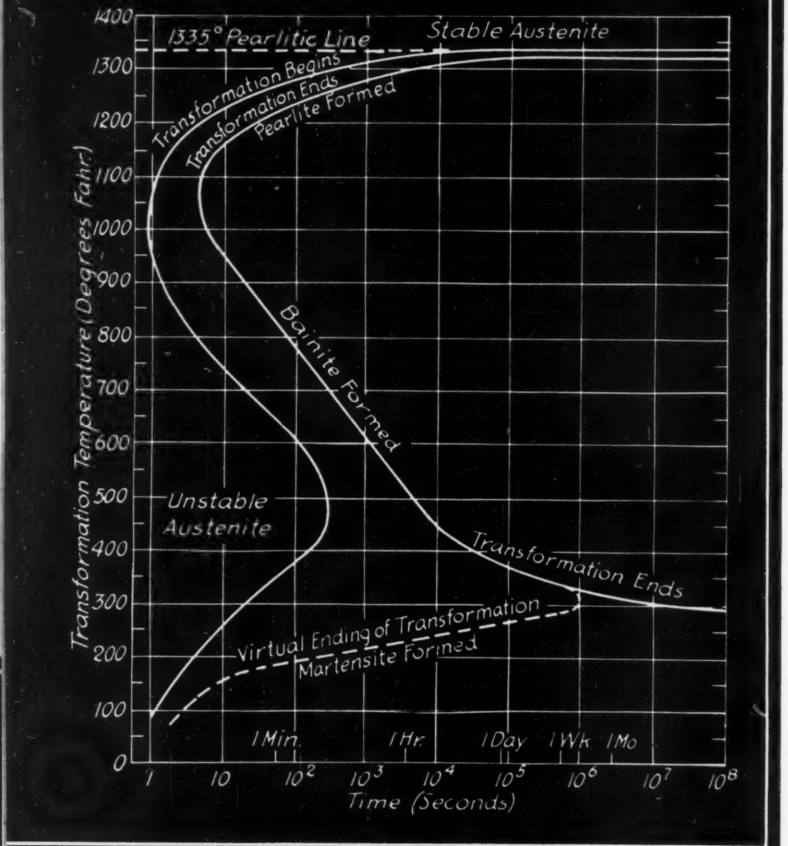


Fig. 28—Initiation and completion curves for the transformation of austenite at constant temperatures for eutectoid carbon steel

Wartime Metal C

By R. E. Orton and W. F. Carter

Acme Steel Co., Chicago

SINCE carbon is the essential element in the hardening of steel by heat treatment, it is logical to discuss first the iron-carbon alloy without consideration of any other element. It is recognized that the combination of iron and carbon alone is not only commercially unattainable but is actually undesirable. Several other elements play important parts in permitting or aiding the reactions, so that their presence is necessary. For the sake of this discussion it will be assumed that these elements are present in adequate quantity. The specific effect of each will be discussed later.

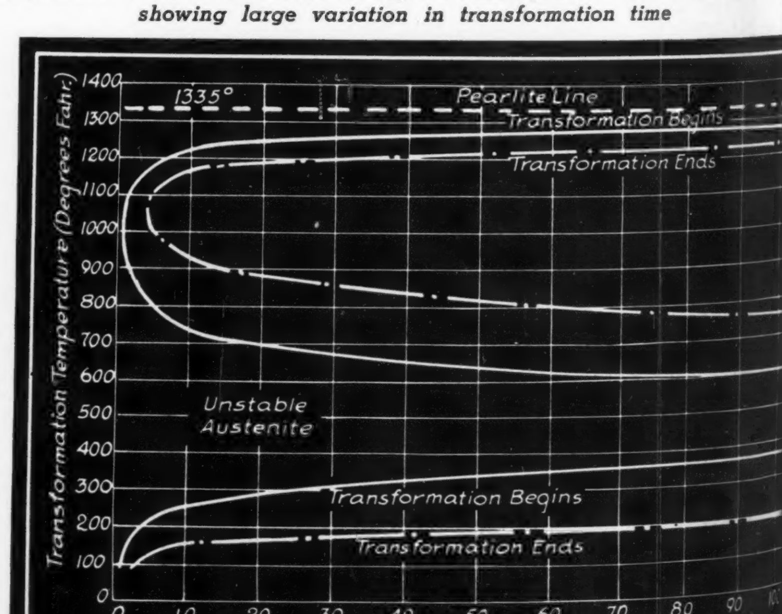
Primary reason for alloying carbon steel is the effect that the alloying elements have on the iron-carbon relationship. Nevertheless, the practice has developed of additions far beyond those needed to influence this relationship (except for very large sections) because of some real or fancied benefit to be gained by this excess. Even though it may be proved that some particular physical quality is improved, in many cases the improved quality is not needed. For example, certain alloys are reported as excellent for resisting grain growth at high temperatures. However, of what value to the application is this quality if the carburizing is to be done at the lower temperature usual with gas carburizing, or if the part is to be slowly cooled from the high temperature and then reheated for the quench? The reheating will refine the originally coarsened grain, making the alloy addition totally unnecessary.

Recognition of these facts permitted the development of the National Emergency specifications or N.E. steels[1]. Careful examination of these new steels shows there is a great deal to commend them. They have sufficient alloys so that, together with the plain carbon steels, they will cover probably 90 per cent of industrial applications and a larger proportion of our actual war goods than is commonly realized. While there may be slight changes and modifications from time to time, there seems little question but that they constitute another "permanent substitution" born of the war. The key to an understanding of why these steels with their low alloying content will serve lies in an understanding of the theory of hardening of plain carbon steels.

As brought out in the preceding article, austenite is the solid solution of carbon in gamma iron. On slow cooling through the critical range, after the rejection of the ferrite or carbide existing in excess of the eutectoid composition, the remaining austenite is transformed into the lamellar structure known as pearlite. *Fig.* 25 of the

1. See MACHINE DESIGN, July, 1942, Page 65, "New Steels Conserve Vital Alloying Elements", also October, 1942, Pages 15 and 151.

Fig. 29—Portion of the curves for Fig. 28 with equal-interval time scale, showing large variation in transformation time



Conserves Strategic Materials

Part IV—Quenched and Tempered Carbon Steel

previous article illustrates the temperature-structure relation for infinitely slow cooling, *Fig.* 20 the structure of pearlite, and *Fig.* 24 the spheroidized condition of the carbide obtained by long holding just below the critical.

Ferrite (pure iron) is an exceedingly soft and ductile material; iron carbide, on the other hand, is hard and brittle. The mere presence of the latter probably strengthens somewhat the ferrite matrix, but the matter of how it is present will have a far more profound effect. Variations in the hardness of steel due to the different heat processings is due essentially to variations in the form and in the size of the carbide particles, which more or less strengthen by their interference with slip along atomic planes.

Carbide will offer the least interference if gathered together into relatively large balls. Slip may easily occur between the balls. If necessary to promote fracture, a ball may even be torn bodily from its seat without actually fracturing through it. This is why the spheroidized structure is the softest form in which steel of a given analysis can exist.

If the carbide were distributed as a series of plates it would strengthen the steel more than when in the spheroid form because a plate would not be as easy to pull out as a sphere; it would be necessary instead to fracture through it. Nor would there exist as many potential slip planes between the plates as with the spheres. However, in a hypoeutectoid steel, slip could still be initiated in the free ferrite so that the strength of the whole would not be that of the individual pearlite grains, but rather the "statistical average" of the pearlite and ferrite.

If the ferrite regions were broken up, the grains being at the same time smaller and the carbide lamellae finer, failure could not occur so easily and a definite improvement in the strength and hardness would be noted. This increase in hardness would continue down to the emulsified pearlitic structure illustrated by *Fig.* 27 of the preceding article.

Slow cooling permits transformation at a high temperature. The different structures obtained by various rates of slow cooling, from coarse lamellar pearlite down through the range to emulsified pearlite, are the result of varying the transformation temperature. It is common knowledge that the fully hardened structure of steel is

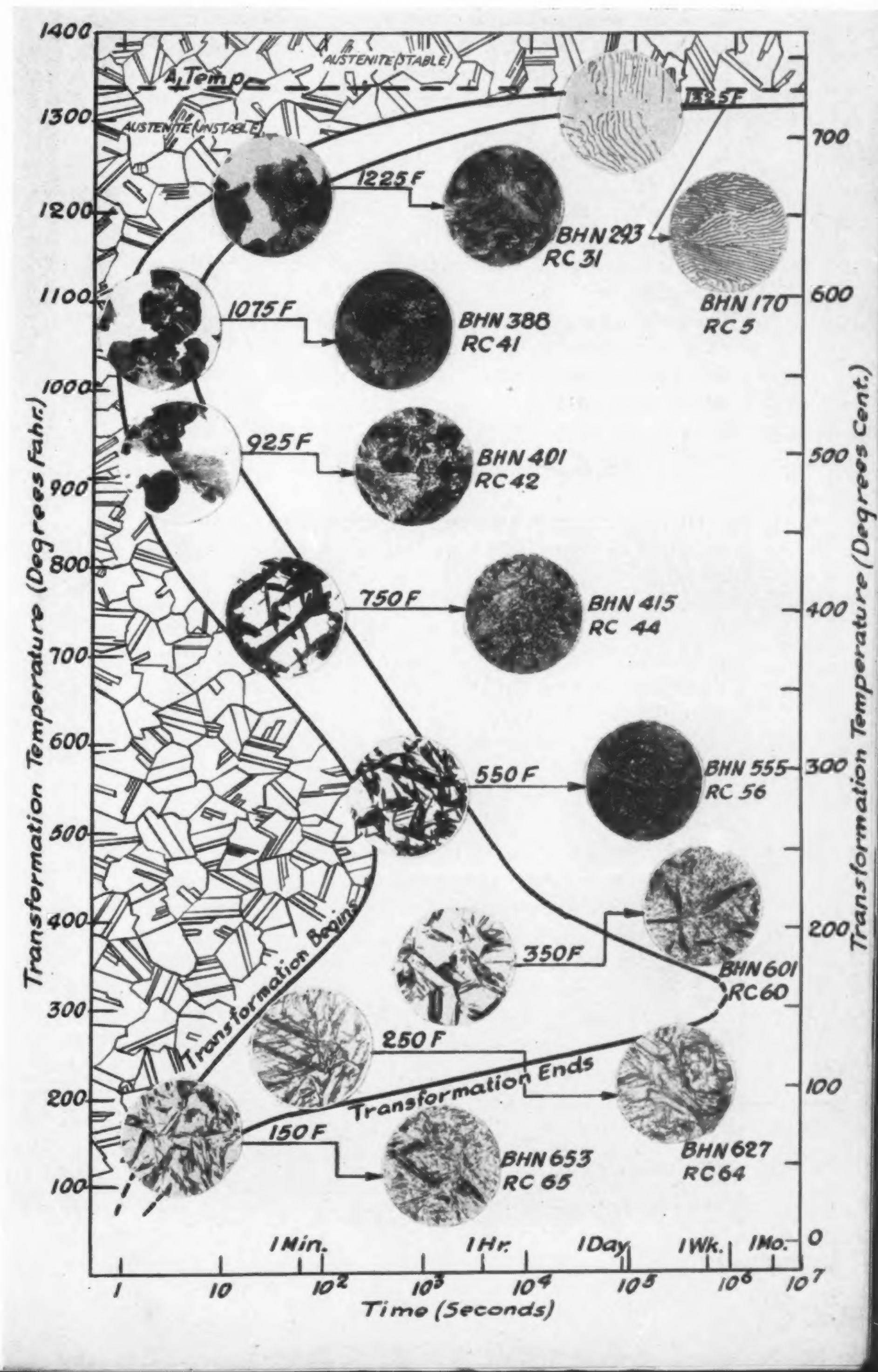


Fig. 30—Austenite transformation at constant temperature for eutectoid steel, indicating structure and hardness for various temperatures. Photomicrographs are at 400 diameters.

Courtesy U. S. Steel Corp.

Fig. 31—Martensitic structure of .7 per cent carbon steel, quenched to full hardness. Brinell 700; 500 diameters

obtained by quenching, that is, by an extremely rapid rate of cooling. The purpose of quenching is not the ostensible one of rapid rate of cooling, but rather to lower the temperature to some low value before transformation can start, and then to complete the transformation at or below that temperature.

The progress of metallography was slow previous to recognition of the significance of the above facts, because in varying the rate of cooling there was but little control of the transformation temperature. A slight change in the cooling rate, or a change in the time lag due to some unrecognized variation in the steel, would cause a radical change in the temperature at which the transformation was initiated. Moreover, the continuing of the cooling meant a continual change in the temperature of transformation. As a result, the part that changed first might exhibit totally different qualities from that which changed last.

Molten-metal Quench Approaches Ideal

Obviously then, the theoretically perfect way to analyze would be to lower the temperature of a specimen from the austenite temperature to some subcritical temperature instantaneously, and then hold at that temperature until the transformation has been completed. This ideal was approached by Bain and Davenport, as described in their historic paper[2], by quenching in molten metals. The plotting of the time of initiation and time of completion of the transformation, against the transformation temperature gives what has been termed the "S-curves of transformation." The initiation and completion curves for a eutectoid steel are presented in *Fig.* 28. The time scale is logarithmic. This is made necessary by the large variation in the time values. To give some concept of this variation a portion of the curves is replotted with regular coordinates in *Fig.* 29.

Examination of the curves of *Fig.* 28 shows that if the specimen is maintained at or above the pearlitic line it remains austenitic indefinitely. If lowered to 1300 degrees it will require six minutes for the transformation to begin and an hour and forty minutes for it to be completed. At 1200 degrees, on the other hand, transformation will begin in four seconds and be completed twenty-three seconds later. At 1050 degrees, the shortest time of all, transformation is initiated in ⅞-second, and is completed only 3¼ seconds later. McQuaid[3] has termed this shortest time the "gate" of the curve because metal must be cooled down past this point, in less time, to avoid being partially or wholly transformed before reaching lower temperatures; that is, it must "squeeze through this gate" to avail itself of lower transformation temperatures.

Below this point more time is available. At 450 degrees some 4½ minutes is required to initiate; then the time

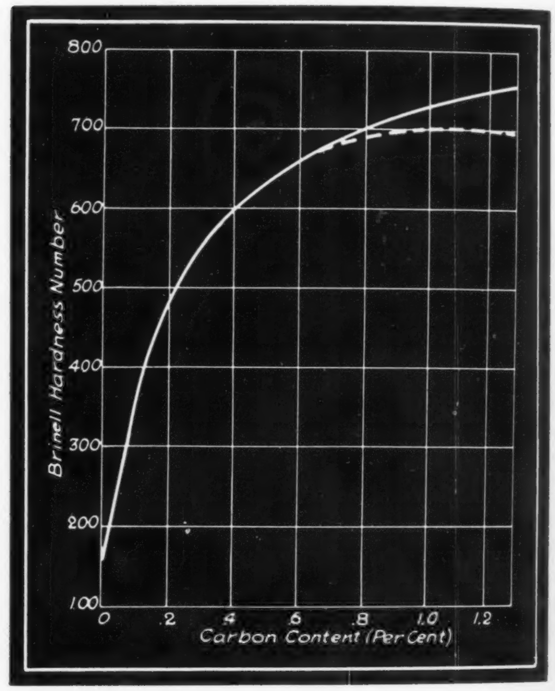


Fig. 32—Variation in hardness with carbon content for fully hardened steel. Dotted curve at high carbon shows usual hardness attained commercially

to initiate again decreases. The time to transform, however, increases markedly until, at about 300 degrees, the "toe" of the curve is reached, at which point the transformation requires weeks, if it is ever completed. Beyond this it would appear that there will always be some austenite retained, at least in steel of this high carbon content, provided that no transformation occurred on the way down to this temperature. Practically all reaction has ceased, however, at the dotted curve marked "virtual ending". The amount remaining untransformed at lower temperatures will generally be less than 1 per cent.

Other Steels Are Similar

The story for steels of other than the eutectoid composition is, qualitatively, substantially the same. The general shape remains, the alteration being primarily in time values. This quantitative change, together with other differences in details, will be the subject of a later discussion.

Reproduced in *Fig.* 30 is the S-curve for carbon eutectoid steel, including photomicrographs and hardness of structures formed at different temperatures. Above the

2. E. S. Davenport and E. C. Bain—"Transformation of Austenite at Constant Subcritical Temperatures", *Transactions*, A.I.M.M.E., Iron and Steel Division, 1930, Page 117.

3. Harry W. McQuaid—"Getting Maximum Results from Carbon and Low Alloy Steels", *Metal Progress*, October, 1941.

gate the various pearlites are obtained. Below the toe gives the structure characteristic of fully hardened steels At the intermediate temperatures is still another structure.

Because of its commercial importance, the fully hardened structure will be examined in detail. It will be assumed that the quenching is sufficiently rapid to get past the gate of the S-curve without any transformation, the complete change occurring below the toe of the curve. If the austenite has been held sufficiently at temperature, the carbon in it will be uniformly distributed in a state of atomic dispersion. When the gamma iron is transformed to alpha at the low temperatures reached by rapid quenching, the rigidity of the lattice structure of the iron is such that the carbide remains as formed, i.e., in a state of molecular dispersion. This structure is known as "martensite" after A. Martens, a pioneer in the field of metallography. Contrary to lamellar pearlite, martensite does not have a definite carbon content. Its structure is illustrated by the photomicrograph of *Fig.* 31.

The hardness of martensite, as with other structures, depends upon the number of keying particles. Since, for a given quantity of carbide, the smaller the particles the larger their number, it follows that the hardness is

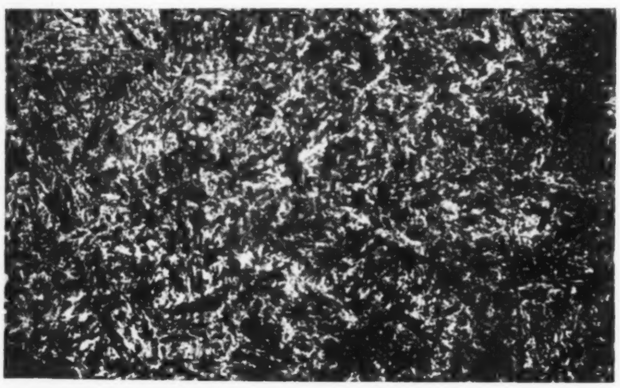


Fig. 33—Martensite tempered at 400 degrees for .7 per cent carbon steel. Brinell 615; 500 diameters

greater the smaller the particle size. Therefore, for a given carbon content, martensite is the hardest known form of steel. *Fig.* 32 is a chart of hardness plotted against carbon content, the upper curve being for 100 per cent martensitic structure and the lower curve giving the values which are more to be expected in commercial practice. It illustrates, so to speak, the capacity of the steel for hardness. The only "catch" is the obtaining of the fully martensitic structure, which is a matter of the needed speed of cooling as compared with that furnished by the quench.

Pure Martensite Is Seldom Obtained

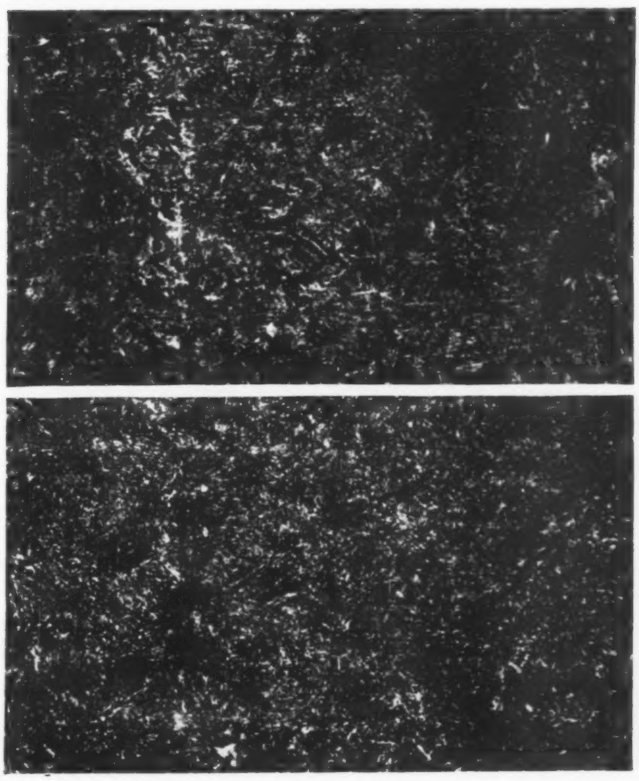
It would be expected that, what with the submicroscopic grain size and the molecular dispersion of the carbides, the microstructure of martensite would show little but a smooth, highly reflective surface. There are several reasons for the mottled structure of *Fig.* 31. The carbide tends to drop out along the atomic planes of the austenite grains existing at the time the martensite is formed. The impurities are not picked up by nor diffused through the austenite as fast as the carbon and they tend to drop out of the austenite sooner. As will be brought out later, it is almost impossible to obtain pure martensite, there nearly always being some emulsified pearlite or retained austenite present. The uneven etching rate due to the lack of uniform distribution of these materials accounts for the appearance of the martensite.

With noneutectoid steels there is still another difference. With hypereutectoid the absorption of the free carbide, even with temperatures above the carbide line (*Fig.* 25) is sluggish. As a result there are apt to be thin plates of pure carbide in even the fully quenched structure, giving an appearance of needles distributed through the matrix. These thin hard plates of carbide contribute greatly to the high wear resistance of hypereutectoid steels without adding much to the hardness. They also, by their breaking up of the matrix, contribute considerably to brittleness. With the hypoeutectoid there may be some free ferrite, with consequent lowering of hardness.

Is Unsatisfactory for Most Applications

Martensite as formed is itself too brittle for most applications. In addition, it contains high internal quenching stresses that make it undesirable for any application. If the temperature of the steel is raised somewhat and held for a short time, agglomeration of the carbide particles and some release of quenching stresses occur. The extent of the agglomeration depends upon the flexibility of the ferrite in permitting the movement of the carbide molecules and upon the distortion its lattice structure will permit to accommodate the increase in the size of

Fig. 34—Martensite tempered in the intermediate temperature range for .7 per cent carbon steel at 500 diameters. Upper micro, 600 degrees, brinell 460; lower, 800 degrees, brinell 415



the particles. Theoretically, at least, above about 250 degrees some diffusion will always occur. This diffusion will be rapid at first but, as the particles get larger, it decreases greatly in speed. The first stage will be over in a matter of minutes whereas the last is a matter of years.

The result of the foregoing is that, for practical purposes, a definite particle size corresponds to each "tempering" temperature and, therefore, to definite physical properties. If higher temperatures are used to give the larger particles with higher ductility due to the greater profusion of slip planes, of necessity, strength is for the same reason lost. Contrariwise, if low temperatures are used, remaining nearer the quenched structure to retain the greater keying effect, the gain in strength is at the sacrifice of ductility. Both high strength and high ductility may not be had. Here is where the designer must exercise his judgment, selecting the best compromise between these two qualities that the particular application will permit.

Tempering temperatures up to 400 degrees are generally used where hardness and wear resistance are the prime requisites. *Fig.* 33 shows the microstructure characteristic of this range.

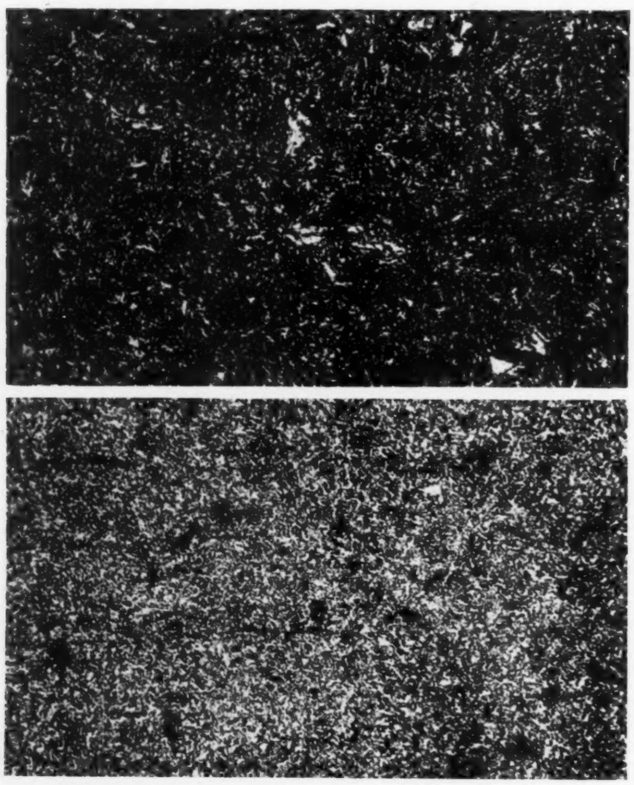


Fig. 35—Martensite tempered in the high temperature range for .7 per cent carbon steel at 500 diameters. Upper micro, 1000 degrees, brinell 310; lower 1200 degrees, brinell 230. Particle size is becoming apparent

Temperatures from 400 to 800 degrees give intermediate properties, and therefore probably are not as widely used. *Fig.* 34 illustrates the structures at 600 and 800 degrees. The change in appearance which was becoming apparent at 400 degrees has now become pronounced. While the characteristic appearance of the martensitic structure may still be traced it has almost disappeared, particularly at 800 degrees tempering temperature. This is due to the agglomeration of the carbide particles which, though still definitely submicroscopic in size, are large enough so that the uneven etching scatters the light rays. This range gives the darkest etching structure of hardened steel.

The range from 800 to 1200 degrees gives the best combination of properties for parts performing structural functions, such as shafts, shock-loaded and very large gears, etc. For the same hardness, the ductility and shock resistance are considerably improved over that obtained with the emulsified pearlitic structure described in the last article. *Fig.* 35 illustrates the structures characteristic of this range. Particle size is beginning to become apparent, the specimen etching much lighter.

At these higher temperatures the agglomeration of the carbide particles continues at a much higher rate than at the lower temperatures, although it is still a matter of hours. By raising the temperature to 1300 degrees (just under the critical) and holding for a number of hours, the agglomeration proceeds to very large particles. This is the spheroidized structure of *Fig.* 24 of the preceding article. Thus it appears, as would be expected, that this structure is the end product of both pearlite and martensite. It should be noted that under no circumstances can the lamellar or emulsified structure of pearlite, obtained by transformation at high temperatures be obtained by the tempering of martensite. The only way martensite may be returned to pearlite is by heating to more than the critical followed by slow cooling.

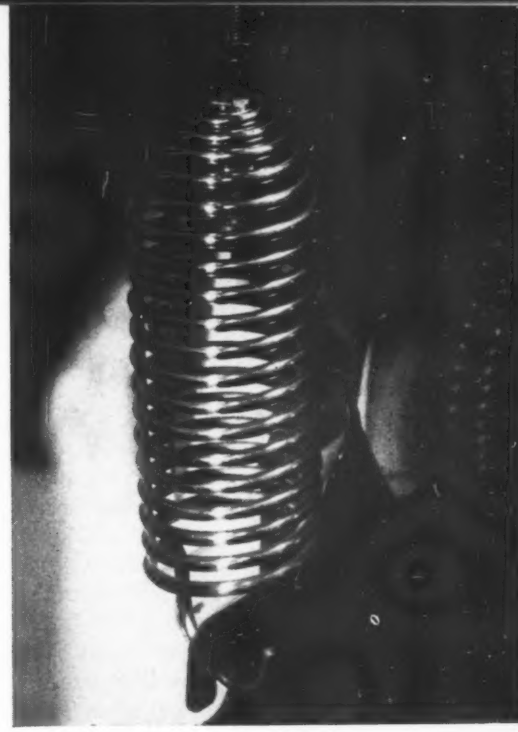
Bainite Has Improved Ductility

There remains to discuss the structures formed at isothermal transformation in the range of temperatures between the gate and the toe of the S-curve. These structures may not be obtained by the usual quenching methods but must be developed by isothermal transformation. Metallographists do not agree regarding the microstructure at this intermediate range of temperatures. For the time being it may be treated as a new constituent, neither pearlite nor martensite. To this structure the term "bainite" has been assigned after Dr. E. C. Bain, who has been responsible for much of the work leading to the isothermal curves. The process of obtaining this structure has been defined as "austempering". The product is said to have unusual ductility for the same hardness as a tempered martensitic structure. Its structure is illustrated in *Fig.* 30. To the writers it seems highly probable that this structure is the same, or nearly the same, as that obtained by tempering quenched martensite at the same temperature as that of the isothermal transformation. The improved ductility and impact resistance may be explained on the basis of the fact that the quenching stresses are greatly reduced in the transformation at the higher temperature. There is evidence to show, in fact, that quenched martensite has at times minute cracks and fissures. These microscopic cracks, incipient sources of failure, have not been found in ehe bainite.

Attractive as it is in the range of hardness from 450 to 550 brinell, the austempering process has not been widely applied, due in part to the difficulties of carrying out the process and because it is only applicable to relatively small sections.

Part V will discuss hardenability of steel.

Which Spring Material?



By A. M. Wahl
Westinghouse Research Laboratories

WARTIME restrictions now being placed on various spring materials make it desirable that designers become familiar with the characteristics of these materials and with the possibilities for substitution. With this thought in mind the present article, consisting essentially of a summary of the properties, composition, method of manufacture, and uses of the more important spring materials, has been prepared. The article is supplementary to a previous one[1] in which materials were considered primarily from the standpoint of fatigue or endurance properties.

In the choice of spring materials it should be borne in mind that, wherever possible, in view of present restrictions, plain carbon steels such as music wire, oil-tempered wire or hot-rolled high-carbon steels should be used instead of alloy steels, stainless steel, and nonferrous materials. In many practical applications substitutions should be possible without loss of essential properties.

Music Wire: A high-quality carbon steel, this wire is used widely for small-sized helical springs, particularly those subject to severe stress conditions. High strength is obtained from a steel of about .7 to 1 per cent carbon, cold drawn to size. The composition as specified by ASTM specification A228-41 is given in Table I. This specification also calls for minimum and maximum tensile strength values as shown by the upper and lower curves of *Fig.* 1. As will be seen from these curves, the tensile strength of music wire may vary from 255,000 pounds per square inch for the larger wire sizes to 440,000 pounds per square inch for the smaller. Carbon content usually will vary with the wire size, the smaller sizes having lower amounts. Some specifications call for a limited range within .1 per cent in carbon content for a given wire size. Music wire is not often used for springs larger than ⅛-inch wire diameter. Typical physical properties are summarized in Table II.

[1] Machine Design, October, 1940, Page 56.

In forming helical springs of music wire, winding is done cold over a mandrel. After winding, the springs usually are given a low-temperature heat treatment to relieve coiling stresses. This bluing treatment calls for heating the springs to a temperature of around 500 degrees Fahr. for one hour for the larger sizes and from 15 to 30 minutes for the smaller sizes.

Formerly music wire was made principally from Swedish steels because of their uniformity and high quality. At present, American steels are being used with satisfactory results in most cases.

Music wire may also be obtained with cadmium-plated surfaces for applications where corrosion is present. In the application of the coating, care must be taken to guard against hydrogen embrittlement. In certain applications where corrosion is a factor, cadmium-plated springs may offer a satisfactory substitute for 18-8 stainless.

Oil-tempered Spring Wire: This is a good quality, high-carbon steel wire made by the open hearth or electric furnace process, and used for cold-wound springs. ASTM specification A229-41 calls for the compositions listed in Table I, composition *A* being pre-

Table I

Composition of Various Spring Materials
(ASTM Standard Specifications)

Material	ASTM Specification	Carbon (%)	Manganese (%)	Phosphorus (max. %)	Sulphur (max. %)	Silicon (%)	Chromium (%)	Vanadium (%)
Music wire	A228-41	.70 to 1	.20 to .60	.03	.03	.12 to .30		
Oil-tempered wire over $\frac{7}{32}$ dia. (comp. *A*)	A229-41	.55 to .75	.80 to 1.20	.045	.050	.10 to .30		
Oil-tempered wire under $\frac{7}{32}$ dia. (comp. *B*)	A229-41	.55 to .75	.60 to .90	.045	.050	.10 to .30		
Hard-drawn spring wire	A227-41	.45 to .75	.60 to 1.20	.045	.050	.10 to .30		
Hot-wound carbon steel helical springs*	A 68-39	.90 to 1.05	.25 to .50	.05	.05	.15		
Chrome-vanadium valve spring wire†	A232-41	.45 to .55	.60 to .90	.03	.03	.12 to .30	.80 to 1.10	.15 to .25

*Heat treated after forming.
†For ordinary chrome-vanadium wire, somewhat higher amounts of phosphorus (.04%) and sulphur (.05%) are allowed.

ferred for sizes over 7/32-inch.

In manufacturing, the wire is cold drawn to size and then heat-treated. Upper and lower limits for tensile ultimate strengths for oil-tempered wire as given by the above specification are plotted against wire size in *Fig*. 2. Further limitations call for a variation in tensile strength of not more than 30,000 pounds per square inch in a single lot in sizes below .12-inch and not more than 25,000 pounds per square inch in sizes above .12-inch. It will be noted that the tensile strengths of this wire are somewhat below the values for corresponding sizes of music wire, *Fig*. 1. Other properties are listed in Table II.

Table II

Tensile Properties of Typical Spring Steels

Material	Ultimate tensile strength (psi)	Elastic limit in tension (psi)	Modulus of Elasticity (psi)	Elongation in 2 inches (%)	Modulus of Rigidity* (psi)
Hard-drawn spring wire ..	160,000 to 310,000†	60% of *T.S.*‡	28,500,000	5	11,400,000
Oil-tempered spring wire ..	170,000 to 310,000†	70 to 85% of *T.S.*	28,500,000	8	11,400,000
Music wire	255,000 to 440,000†	60 to 75% of *T.S.*	30,000,000	8	12,000,000
Annealed high-carbon wire	250,000 to 300,000	200.000 to 275,000	30,000,000	7	11,500,000
Hot-rolled high-carbon steel	175,000 to 195,000	75 to 85% of *T.S.*	29,000,000	6	10,500,000§
Chrome-vanadium steel ..	210,000 to 300,000	80 to 90% of *T.S.*	30,000,000	10	11,500,000

†Depending on size.
‡*T.S.*=Tensile strength.
*See article in Machine Design, August, 1939, for further data on modulus of rigidity.
§Low value probably due to surface decarburization.

As in the case of music wire, springs of oil-tempered wire usually are wound cold and then given a thermal treatment to relieve coiling stresses. This is done by heating at 500-535 degrees Fahr. for one-half hour.

Hard-Drawn Spring Wire: Of lower quality than music or oil-tempered wire, this carbon steel may be used in cases where the stresses are low or where a high degree of uniformity is not so essential. The chemical composition as specified by ASTM specification A227-41 is given in Table I. This specification requires that the carbon in any one lot of material shall not vary by more than .2 per cent and the manganese by not more than .3 per cent. Usually the higher carbon contents are used for the larger wire sizes to obtain higher tensile values.

Minimum and maximum values of ultimate tensile strengths for hard-drawn wire are shown by the dashed lines in *Fig*. 2 as a function of wire diameter. Winding is done cold, followed by a thermal treatment.

Annealed Wire Utilized for Severe Forming

Annealed High-Carbon Wire: With high ductility in the annealed state, this material is utilized in cases where severe forming operations are necessary in the manufacture of the spring such as, for example, in torsion springs with certain shapes of end turns. The springs are first formed from the annealed wire and then heat treated after winding to obtain the required physical properties. A typical specification for this material calls for the following composition:

Carbon	.8 to .95%
Manganese (max)	.50%
Phosphorus (max)	.03%
Sulphur (max)	.03%

Approximate physical properties as obtained after heat treatment are listed in Table II.

Hot-Wound Helical Springs, Heat Treated After Forming: For the larger sizes of helical springs, over ⅜-inch wire diameter, it is not practical to wind the springs cold. In such cases they are wound hot from either hot-rolled carbon or alloy-steel bars and then heat treated. For carbon steel bars the composition required by ASTM specification A68-39 is given in Table I.

In winding these springs, they are heated to a temperature of 1700 degrees Fahr. and coiled on a preheated mandrel. The springs are then allowed to cool uniformly to a black heat, after which they are heated to a temperature around 1475-1500 degrees Fahr. and quenched in oil. After quenching, the springs are tempered by heating to 800 degrees in a salt bath. This gives a hardness around 375 to 425 brinell. Typical physical properties of the material are shown on Table II.

Chrome-Vanadium Steel Wire: In the past this alloy-steel wire has been frequently specified where a high quality material is needed and where temperatures are somewhat higher than normal, such as in the case of automotive valve springs. Because of present restrictions on alloy steels, however, use should be avoided where possible. In this connection it should be noted that relaxation tests by Zimmerli[2] did not show a marked superiority of chrome-vanadium steel over certain carbon steels with respect to resistance to creep and relaxation.

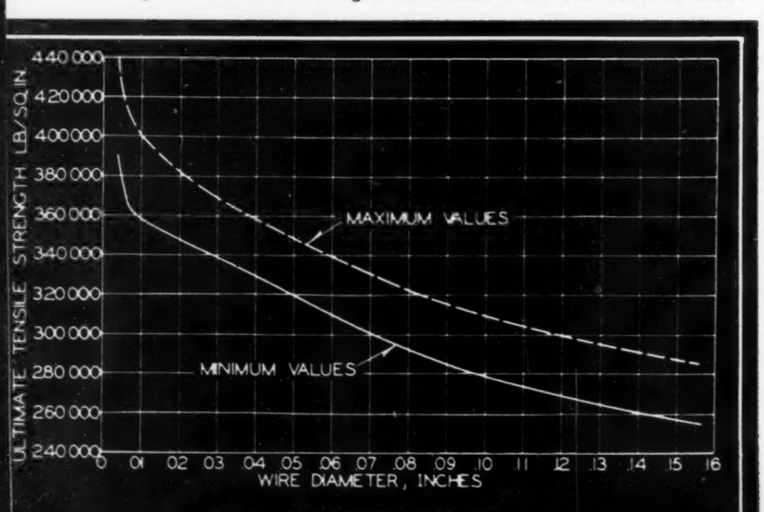
Composition of chrome-vanadium valve-spring quality wire is listed in Table I. For ordinary chrome-vanadium steel spring wire somewhat higher amounts of phosphorus (.04 per cent) and sulphur (.05 per cent) are allowed.

When wound from annealed wire, springs of this material are heat treated after coiling. If wound from oil-tempered chrome-vanadium wire, a low temperature heat treatment (500-700 degrees Fahr.) is given, the higher bluing temperatures being preferred for applications involving elevated temperatures. Tensile properties of the material are shown in Table II.

Stainless Steel Spring Wire: Stainless steels hav-

[2] "Effect of Temperature on Coiled Steel Springs Under Various Loadings", *Transactions*, A.S.M.E., May, 1941, Page 363.

Fig. 1—Tensile strength of music wire for various sizes



ing a composition of about 18 per cent chromium and 8 per cent nickel are used widely for springs subject to corrosion. They are also of value for elevated temperature conditions. A typical specification for this material is:

Carbon (max)	.15%
Chromium	16 to 20%
Nickel	8 to 12%
Nickel plus Chromium....	26% (min)

Tensile strength is developed by cold drawing and may vary from 160,000 to 320,000 pounds per square inch, depending on the size, as shown in the following table:

18-8 Stainless Steel Spring Wire

Wire size (in.)	Ultimate tensile, strength (psi)	Wire size (in.)	Ultimate tensile strength (psi)
.0104	320,000	.0915	234,000
.0135	313,000	.148	207,000
.0173	306,000	.207	185,000
.0258	288,000	.263	171,000
.0410	269,000	.307	162,000
.0625	251,000		

Other properties of this steel are listed in Table III.

Springs of 18-8 stainless steel wire are wound cold and usually given a stress-relieving heat treatment at a temperature of 750 degrees for 15 minutes to an hour.

Phosphor Bronze: Finding its greatest use in cases where a spring with good electrical conductivity is desired, phosphor bronze is also used in applications where corrosion resistance is important. At present, however, because of high tin content (5 to 8 per cent) its use is severely restricted. A possible substitute where high conductivity is desired is beryllium copper. Typical properties of two phosphor bronzes are given in Table III.

Beryllium Copper: An alloy consisting essentially of about 2 per cent beryllium and the balance copper together with small amounts of other alloys[3], it has the advantage of having a high electrical conductivity while not requiring tin in its manufacture. In general, wire of this material is quenched from 1475 degrees Fahr. and then cold drawn to increase the hardness. After coiling, it is heat treated to increase the physical properties. This treatment is varied to change the modulus of elasticity or the amount of drift or creep. Further data on properties are given in Table III.

K-Monel: This is a copper-nickel alloy to which 2 to 4 per cent aluminum has been added. A typical composition is: Copper 29 per cent, nickel 66 per cent, aluminum 2.75 per cent. Wire of this material is given a solution heat treatment and then is cold drawn. After winding, the springs are given a final heat treatment to increase the hardness and strength. By this means ultimate strengths around 170,000 to 200,000 pounds per square inch can be obtained. Further data on physical properties are given in Table III. Springs of this alloy are used for corrosion conditions and for resistance to elevated temperatures.[4]

[3] See articles by R. W. Carson, "Springs of Beryllium Copper", *Aero Digest*, July, 1942, and "New Alloys for Springs", *Product Engineering*, June, 1938, for additional data on this alloy.

[4] Article by Betty, et al., *Transactions*, A.S.M.E., July, 1942, Page 465, for data on relaxation resistance of this and other nickel alloys at elevated temperatures.

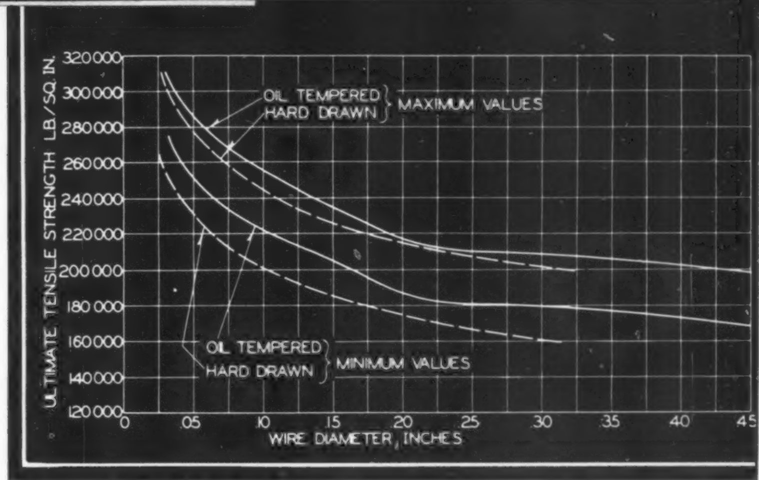


Fig. 2—Ultimate tensile strength for hard-drawn and oil-tempered spring wire

Z-Nickel: A corrosion resistant alloy containing about 98 per cent nickel, this material has good mechanical properties. It is used for springs subject to elevated temperatures. Because it has a fair ductility after heat treatment, springs of this material are often wound from heat-treated wire. Further data are given in Table III.

Other Substitutions for Critical Materials: One which may be considered as a substitute material where corrosion conditions and static loading are involved is copper-clad steel. For spring use, this material consists essentially of a high-strength steel having a thin coating of copper for protection against corrosion. Tensile properties in the heat-treated condition may be obtained which approach those of hot-rolled spring steel, heat-treated. Where fatigue loading is involved, however, it may not be advisable to use springs of this material because of danger of fatigue failure of the relatively weak surface.

Helical springs coiled from glass rods and tempered have also been used for springs under corrosion conditions. The tempering consists in inducing surface compression stresses by suitable heat treatment, thereby greatly increasing the tensile strength. Because of the low tensile strength of glass relative to that of spring steel, even after tempering, much lower working stresses are used in practical design. Since the energy storage capacity of a spring increases as the square of the stress, other things being equal, this means that the glass spring will usually have to be much larger than a corresponding one of spring steel. This is true even though the modulus of elasticity of glass is only one-third that of steel. However, where space is available this material offers some promise for use particularly where corrosion conditions are severe.

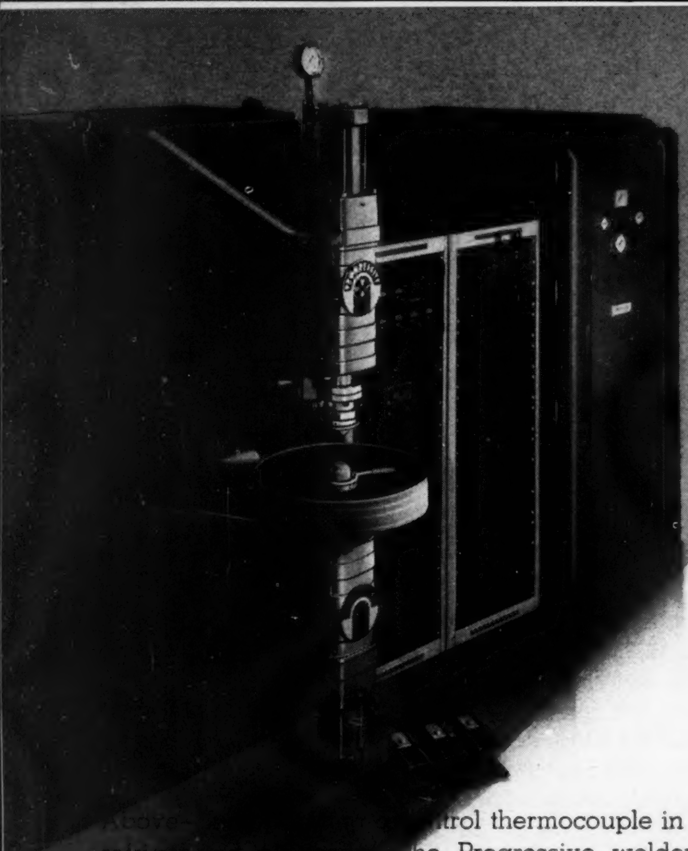
Table III

Physical Properties of Stainless Steels and Nonferrous Metals

(as used in springs)

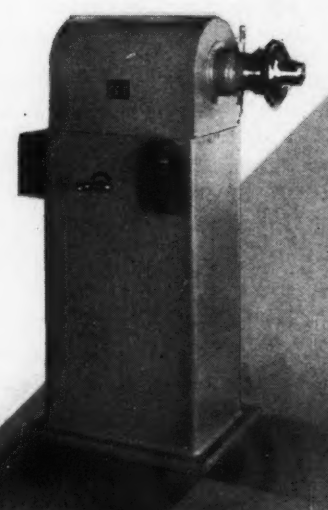
Kind of material	Ultimate tensile strength (psi)	Elastic limit in tension (psi)	Modulus of elasticity (psi)	Elongation in 2 inches (%)	Endurance limit in bending (psi)	Modulus of rigidity (psi)
Stainless steel (18-8) ..	160,000 to 320.000†	50-70% of *T.S.*‡	28,000,000			10,200,000 to 11.200.000
Phosphor bronze (5% tin)	98 000	50.000	14.500.000	2.5		6.000.000
Phosphor bronze (8% tin)	112,000	55,000	14,000,000	3		6,000,000
K-monel (spring temper heat-treated)	170 000 to 200,000	80,000	26,000,000	3 to 8	50,000	9,500,000
Beryllium copper	180,000 to 225,000	.....	19,000,000	1 to 2	40,000	7,500,000
Z-nickel (spring temper heat treated)	200,000 to 240,000	.....	30,000,000	5 to 10	.....	11,000,000

†Depending on size.
‡T.S.=Tensile strength.



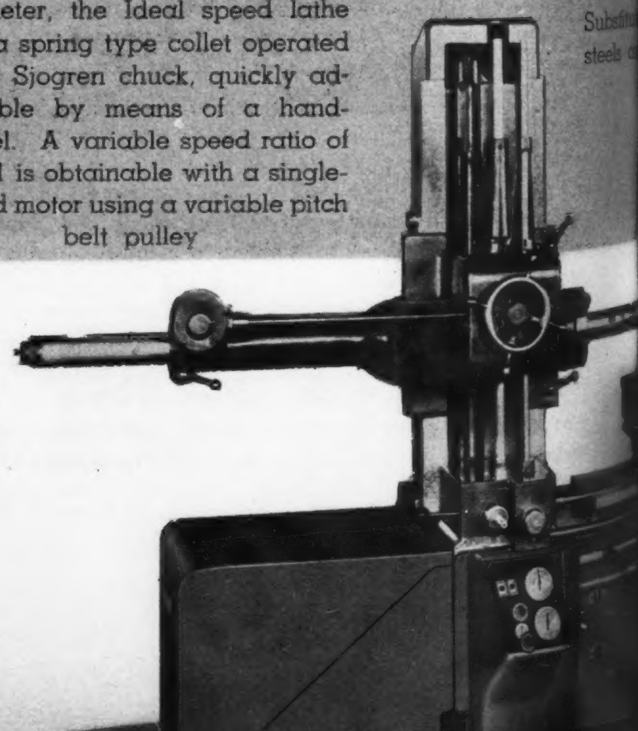
Right — Counterweight operating in a fluid cylinder and attached by a steel tape to the gaging unit of the Sheffield lead measuring device controls the speed of travel and eases the unit against the micrometer or measuring standard without shock. Pressure created in the gaging mechanism is only three ounces, enabling accurate checking of fine threads

Above—[illegible] control thermocouple in the refrigerated electrode of the Progressive welder is designed to produce uniform spot welds regardless of metal thickness, cleanliness of surfaces or other welding conditions. It also subjects the completed weld to a heat-treating cycle for grain refinement and tempering, the thermocouple controlling the start of heating and cooling at preselected temperatures



Below—Assembling, pressing and straightening operations are facilitated by use of the 100-ton open-side Denison press. Of welded construction with a cast steel cylinder and a polished steel ram, the press has a maximum stroke of 18 inches. Power transmission medium is oil, while either manual or electric control is available

Above — Designed for finishing, burring, filing, lapping or polishing of screw parts up to 1⅜-inch diameter, the Ideal speed lathe has a spring type collet operated by a Sjogren chuck, quickly adjustable by means of a handwheel. A variable speed ratio of 6 to 1 is obtainable with a single-speed motor using a variable pitch belt pulley



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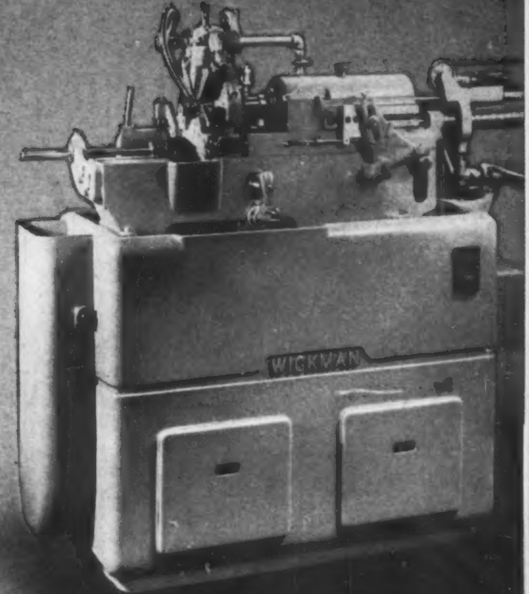
gears

Left—Developed for finishing small gears such as are used in range finders and bomb sights, the National Broach gear shaver incorporates the principle of rotary crossed axes, using a gashed helical cutter which drives the work gear as it is being cut. Cutter head and table are actuated by cam and lever mechanisms. Tailstock spindle is spring loaded to a predetermined pressure sufficient to hold the work without burning the centers



Above—Sliding headstock [illegible] tools working radially make the [illegible] particularly adaptable to the production of [illegible] parts such as striker pins, detonators and [illegible] for fuses. By a combination of cam-controlled headstock and tool movements practically any angle or form can be produced without form tools

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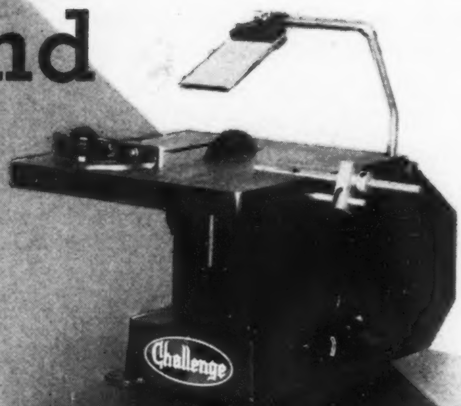
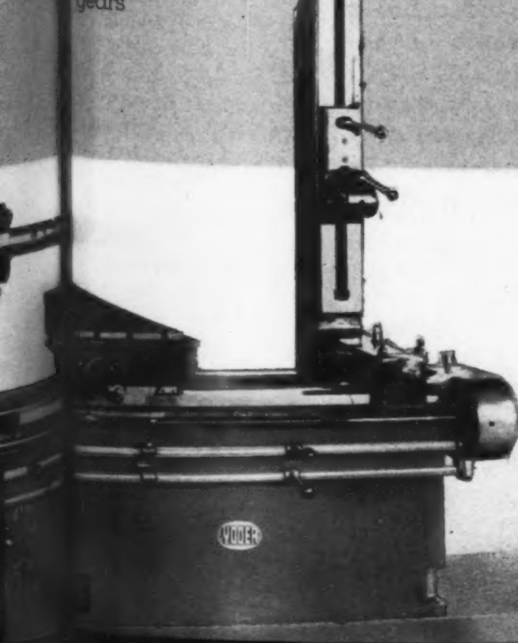
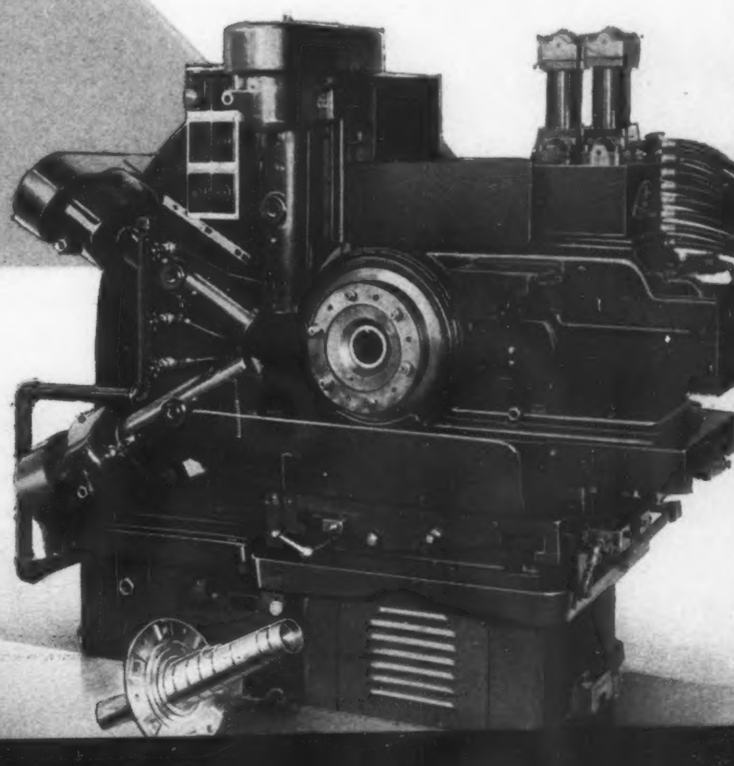


Above—Equipped with an elastic cutoff wheel, the Challenge cutoff machine has a capacity up to one inch round and an adjustable table 14 by 15 inches. Spindle is mounted in ball bearings and the machine is provided with a transparent safety guard

Below—Used in milling an undercut to produce six elevated rest pads on a turned propeller shaft hub, the Snyder three-spindle rotary milling machine is fully automatic except for the throwing of a lever between first and second cycles representing, respectively, rough and finish cuts. Rotation of the fixture during the milling cycle is actuated by hydraulic cylinders which give an adjustable feed rate

Below—... of electric infinitely variabl... ...trol to the Yoder horizon... ...l provides high acceleratio... ...k, shockless stops. Substitu... ...h alloy steels, NE steels ... ...d for drive shafts ... gears





MACHINE DESIGN *Editorial*

Metallurgy Becomes Intimate Part of Design Picture

DEFINITE indications point to the fact that the steel situation, not only from the standpoint of quantity—discussed in previous issues—but also of quality, is not all that it should be. There is vital necessity now for designers to delve into the matter of substitutions even more seriously than in past months, and furthermore to look ahead with still keener foresight to the probability that the substitutes they select may soon become unavailable.

National emergency steels, on which much hope has been pinned as alternatives to the higher alloy steels, evidently will go only part way toward meeting the situation. It already is proving difficult for companies making vital war equipment to obtain adequate samples of these steels for test purposes. It also is practically impossible for builders of production machinery to lay their hands on sufficient quantities to keep them going.

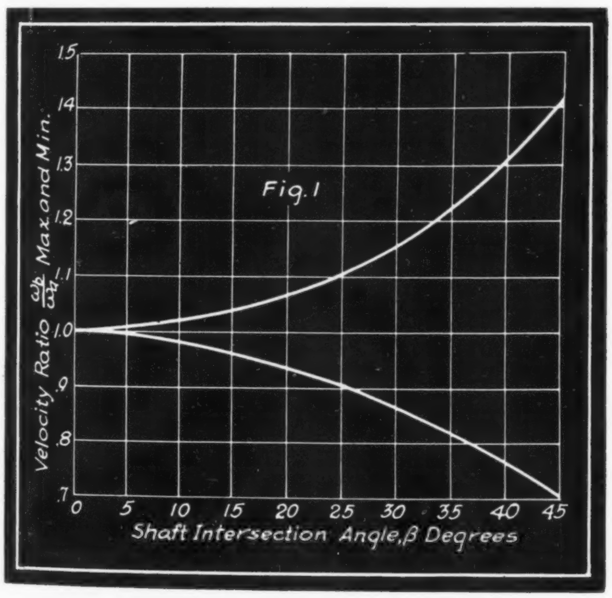
Such conditions undoubtedly will ease somewhat as orderly procedure is established, but it is certain that the higher alloy steels will not become available for anything other than the most vital war needs and that the quantity and quality of the lower alloys will be reduced. For instance, the amount of alloying constituents in the NE steels is dependent to an extent on the alloys residual in the scrap metal used in their production. Quality, because of the wide range in permissible composition of these steels, will necessarily vary and eventually will become lower.

Confronted with these limitations—and possibly even more drastic considerations as time goes on—it behooves designers to associate themselves closely with metallurgists who may be available to assist them, and also to seek as wide an understanding as possible of the intricacies of metallurgy. The series of articles "Wartime Metallurgy", Part IV of which appears elsewhere in this issue, should go far toward developing that grasp of the subject so essential under present circumstances. The series also is planned to assist designers to develop initiative and ingenuity in utilizing to the full the lower alloy and plain carbon steels, thus relieving the demand for higher alloys except for imperative war purposes.

L. E. Jermy

Velocity and Acceleration Analysis of Universal Joints

BECAUSE of simplicity of construction, the conventional universal joint (Hooke's coupling) is widely used in spite of its disadvantage that for a constant driving speed the driven speed varies. Often this characteristic is overcome by employing two such couplings, properly installed in series so that the lag of one compensates for the lead of the other. Whether or not such a double universal joint is used, a knowledge of the variations in angular velocity and acceleration of each one is important when the speed is high. Rotating masses subject to periodic acceleration and deceleration require high



torques, and with certain combinations of mass and elasticity in the connected parts dangerous torsional vibrations may be stimulated through the action of the coupling.

To aid the designer in anticipating any such trouble and incorporating in his design the proper remedy, exact and approximate equations for the angular velocity and acceleration of the driven shaft are presented in this data sheet. Purpose of the exact equations is to enable calculation of the momentary velocity or acceleration at any instant during a revolution. The approximate equations give values of the harmonics which are present in the velocity and acceleration functions. Knowledge of these harmonics is needed in investigating torsional vibration effects.

[1]See, for example, C. D. Albert and F. S. Rogers—*Kinematics of Machinery*, Pages 378-382, John Wiley & Sons Inc.

Speed variation is a function of the shaft intersection angle, and exact equations for driven shaft angle and angular velocity may be easily derived.[1] These equations may be written:

$$\phi = \tan^{-1}(\tan\theta \cos\beta) \qquad (1)$$

and

$$\omega_b = \omega_a \frac{\cos\beta}{1-\sin^2\theta \sin^2\beta} \qquad (2)$$

where β = angle of shaft intersection

θ = angle turned through by driving shaft

ϕ = angle turned through by driven shaft

ω_a = angular velocity of driving shaft

ω_b = angular velocity of driven shaft.

Rewriting Equation (2), with the squares of trigonometric functions expressed in terms of double angles:

$$\frac{\omega_b}{\omega_a} = \frac{\dfrac{4\cos\beta}{3+\cos 2\beta}}{1+\dfrac{1-\cos 2\beta}{3+\cos 2\beta}\cos 2\theta} \qquad (3)$$

$$= \frac{C}{1+D\cos 2\theta} \qquad (4)$$

where $C = \dfrac{4\cos\beta}{3+\cos 2\beta}$

$D = \dfrac{1-\cos 2\beta}{3+\cos 2\beta}$

The angular acceleration of the driven shaft is found by differentiating Equation (4) with respect to time, giving the expression

$$\frac{\alpha_b}{\omega_a^2} = \frac{2CD\sin 2\theta}{(1+D\cos 2\theta)^2} \qquad (5)$$

where α_b = angular acceleration of driven shaft.

Minimum and maximum values of the velocity ratio, ω_b/ω_a, by inspection of Equation (2) are, respectively, $\cos\beta$ and $1/\cos\beta$. These are plotted in *Fig.* 1.

Maximum numerical value of the angular acceleration ratio, α_b/ω_a^2, is found by differentiating Equation (5) with respect to time or θ, and setting the differential equal to zero. This procedure shows that the maximum value occurs when

$$\cos 2\theta = \frac{1}{2D}\left(1-\sqrt{1+8D^2}\right)$$

Substituting this value in Equation (5) gives the actual maximum acceleration ratio. Values are plotted in *Fig.* 2.

While Equations (4) and (5) give the angular velocity and acceleration exactly, they do not reveal what harmonics are present nor their relative magnitudes. To find the harmonics, Equation (4) is first expanded binomially, as follows:

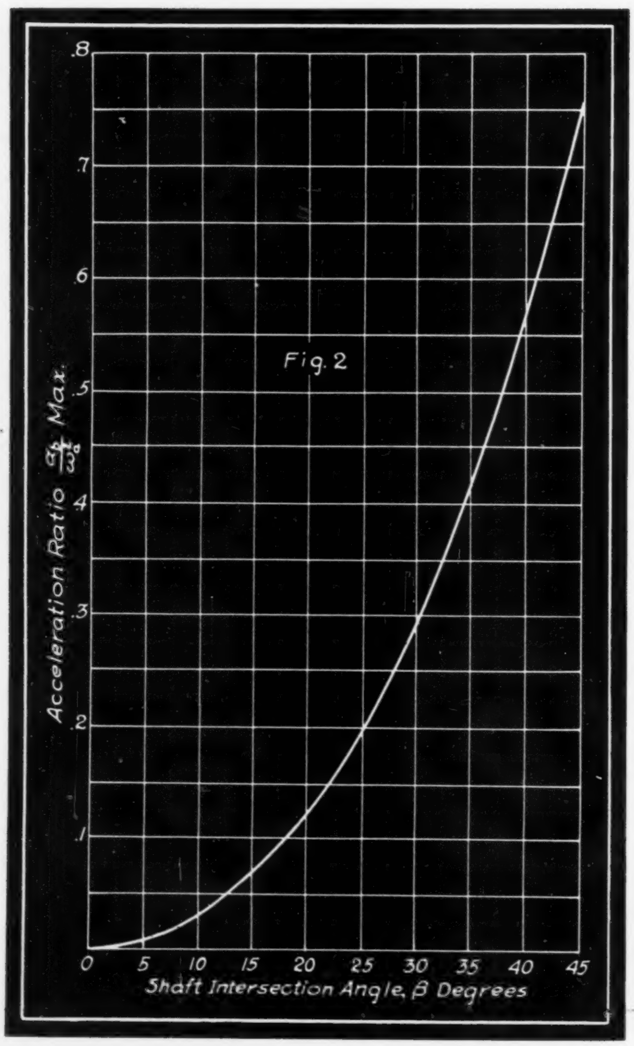
$$\frac{\omega_b}{\omega_a} = \frac{C}{1+D\cos 2\theta}$$
$$= C(1+D\cos 2\theta)^{-1}$$
$$= C(1-D\cos 2\theta + D^2\cos^2 2\theta - D^3\cos^3 2\theta + \text{etc.})$$

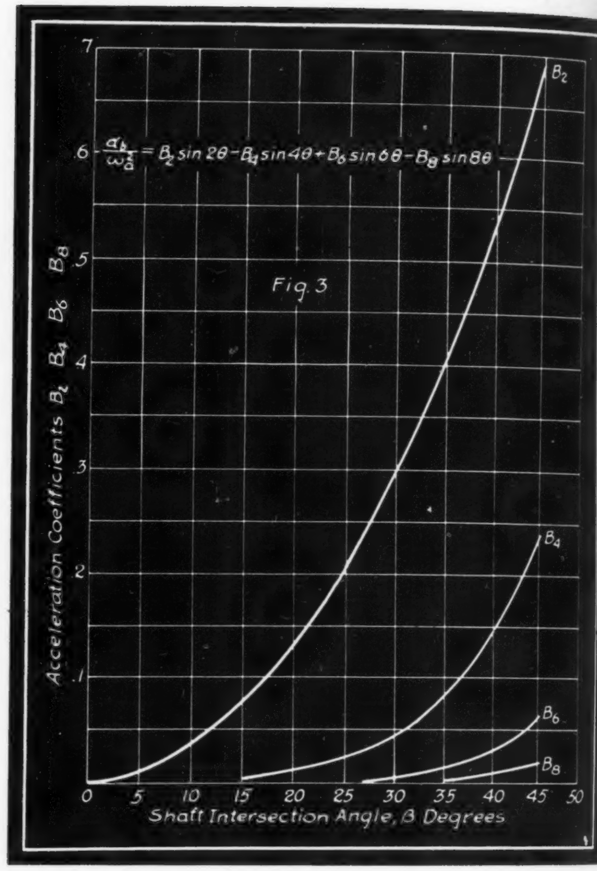
Converting the powers of $\cos 2\theta$ into terms of multiple angles, the final expression, carried as far as necessary for values of β up to 45 degrees, becomes:

$$\frac{\omega_b}{\omega_a} = A_o - A_2\cos 2\theta + A_4\cos 4\theta - A_6\cos 6\theta + A_8\cos 8\theta \quad \text{.........(6)}$$

where $A_o = C\left(1+\frac{D^2}{2}+\frac{3D^4}{8}+\frac{5D^6}{16}+\frac{35D^8}{128}+\text{etc.}\right)=1$

$$A_2 = C\left(D+\frac{3D^3}{4}+\frac{5D^5}{8}+\frac{35D^7}{64}+\text{etc.}\right)$$





$$A_4 = C\left(\frac{D^2}{2}+\frac{D^4}{2}+\frac{15D^6}{32}+\frac{7D^8}{16}+\text{etc.}\right)$$

$$A_6 = C\left(\frac{D^3}{4}+\frac{5D^5}{16}+\frac{21D^7}{64}+\text{etc.}\right)$$

$$A_8 = C\left(\frac{D^4}{8}+\frac{3D^6}{16}+\frac{7D^8}{32}+\text{etc.}\right)$$

The acceleration is found by differentiating Equation (6) with respect to time:

$$\frac{\alpha_b}{\omega_a^2} = 2A_2\sin 2\theta - 4A_4\sin 4\theta + 6A_6\sin 6\theta - 8A_8\sin 8\theta$$
$$= B_2\sin 2\theta - B_4\sin 4\theta + B_6\sin 6\theta - B_8\sin 8\theta \quad \text{..........(7)}$$

where $B_2 = 2A_2 = 2C\left(D+\frac{3D^3}{4}+\frac{5D^5}{8}+\frac{35D^7}{64}+\text{etc.}\right)$

$$B_4 = 4A_4 = 4C\left(\frac{D^2}{2}+\frac{D^4}{2}+\frac{15D^6}{32}+\frac{7D^8}{16}+\text{etc.}\right)$$

$$B_6 = 6A_6 = 6C\left(\frac{D^3}{4}+\frac{5D^5}{16}+\frac{21D^7}{64}+\text{etc.}\right)$$

$$B_8 = 8A_8 = 8C\left(\frac{D^4}{8}+\frac{3D^6}{16}+\frac{7D^8}{32}+\text{etc.}\right)$$

With the aid of the foregoing equations the designer may quickly evaluate the torsional harmonics for any shaft angle, β, where this angle is less than 45 degrees. It is worth noting that the smaller the angle β, the fewer terms need be calculated in the above expressions for the coefficients A_2, B_2, etc. Values of the harmonic coefficients B_2, B_4, B_6 and B_8 are plotted in *Fig.* 3.

PROFESSIONAL VIEWPOINTS

MACHINE DESIGN welcomes comments from readers on subjects of interest to designers. Payment will be made for letters and comments published

" . . . why not use phorograph?"

To the Editor:

Being interested in the article by H. A. Bolz in your May issue entitled "Simplified Graphical Solution of Linkages", I am raising a question that has been bothering me for some time. This question is: Why is there so little recognition of the methods of Angus of the University of Toronto for the analysis of mechanisms?

By Angus' method, known as the phorograph, it is possible to find the linear velocity of any point on any mechanism by a graphical construction that can be made almost as fast as the mechanism itself can be laid out. Also, by a few simple calculations from quantities taken for the construction, the angular velocity of any link relative to any other link may be quickly determined. By a little further construction it is possible to determine the acceleration of any link relative to any other link at any particular time.

Method Proves Satisfactory

I have never been able to find anything wrong with the treatment, but have always felt there must be some fault which causes it to be avoided. Now, however, when Bolz cites the very arguments that lead to Angus' conclusions my curiosity is again aroused. I have personally used the methods of Angus on a number of occasions with highly satisfactory results.

It is difficult to cite in a few words the methods, but an example might serve: Taking the case shown in *Fig.* 1 of Bolz's article, drawing a line from point O_{21} parallel to line BO_{41} and then extending line BA to the intersection of the first line, calling that intersection B^1, the angular velocity ratio of the crank linkage member AO_{21} is equal to B^1O_{21}/BO_{41}. This adds up, practically, to the same thing as Bolz has, as of course B^1O_{21} will be equal to BC. However, the angular velocity ratio of AB with regard to the frame can also be found; it is equal to AB^1/AB and is of opposite sense to that of AO_{21}. Furthermore, the linear speed of the point B, that is the quantity V_B, is equal to $B^1O_{21} \times \omega_2$. What is more, if the linear velocity is desired for a point halfway between A and B, from the middle point of AB^1 noted as N^1, a line is drawn from this point to O_{21}. Now the velocity of the middle point of AB is equal to $O_{21}N^1 \times \omega_2$ and its direction is perpendicular to $O_{21}N^1$.

—R. E. ORTON
Acme Steel Co.

" . . . phorograph is not grasped readily"

To the Editor:

Mr. Orton's comments concerning my article are the kind we members of the teaching profession need and are constantly looking for. It is stimulation of this sort that is helpful.

My method is an alternative to the phorograph. The latter was covered thoroughly in MACHINE DESIGN several years ago in the following articles: "Simplifying the Computation of Velocity Problems" by J. H. Billings in the December 1935 issue, "Phorograph Method Simplifies Velocity and Force Calculations" by M. F. Sayre in September 1934 issue, and "Adapting Phorograph Method to Acceleration" by Sayre in November 1934 issue.

The last paragraph in my article as it appeared implied that my method was the only one not requiring instant centers in its solution. This paragraph was added by the editors without my knowledge. At Purdue University, the phorograph method as well as the velocity polygon or image method have been taught and we are aware of their relative advantages and disadvantages over the instant center method.

Most Engineers Understand Instant Centers

Since most mechanical engineering graduates are familiar with the instant center concept I chose it as the basis for proving my method. After all, I was presenting a special approach to the determination of angular velocity ratios, not a general method of velocity analysis.

While the phorograph is simple to use, it is not easy to teach. The concept of its basic principle of collecting on one line "a set of points each representing the motion of a given point on the machine at the given instant", is not grasped readily by students. This is based upon the experience of our faculty who presented the phorograph to one group of select students as an experiment. The phorograph, it may be observed, occasionally breaks down and requires a cut-and-try solution as Sayre demonstrates. It may be, however, that the use of an auxiliary point as employed in the velocity polygon will obviate the cutting and trying.

The phorograph has one feature worth considering in that relatively untrained draftsmen may be taught to use it mechanically without actually understanding its underlying kinematic foundation. This may be a decided advantage in design departments but loses its force in the field of teaching since engineering students must be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taught to reason out their problems and not to follow strictly mechanical methods.

There is nothing wrong with the Angus treatment but as long as there are more easily understood methods it probably will suffer neglect in already crowded courses, although its advantages might at least be demonstrated to the students.

I am grateful for Mr. Orton's comments. Our machine design staff has discussed his views and we hope that you will present the latter to your readers for the benefit of all. We are well acquainted with Mr. Orton's contributions to your fine magazine and are ready to give his ideas the consideration which they deserve.

—H. A. Bolz
Purdue University

". . . better presented as nomographs"

To the Editor:

As an example of a method of presenting data in chart form, I would like to discuss the article by A. M. Wahl, "When Springs Are Statically Loaded" in your July issue. Charts such as he has presented there represent an enormous amount of work. Practically, however, in my opinion they are not too useful because they are difficult to follow unless they are frequently used. I believe, without studying the problem in detail that the data presented by Wahl could be much better presented in nomographic form with less labor and greater usefulness to the reader.

—R. A. Y.
Chicago

". . . plain charts are more useful"

To the Editor:

Regarding the advantages of nomographic charts, the average reader is not sufficiently familiar with such charts to use them with confidence. Consequently, in my opinion, plain charts such as were used in the writer's July article are more useful to most readers than nomographs. The reason for this is that the average engineer is accustomed to reading curves wherein one variable (say allowable load P or spring deflection δ) is plotted against another variable (say wire diameter d). The charts were nothing more than a series of such curves for different coil diameters. Consequently, I find it hard to believe that such charts are "difficult to follow unless they are frequently used". On the contrary, I believe that they would be much easier to follow by the average reader than nomographic charts. Also to my mind the effect of changes in coil or wire diameters is much more readily apparent when the data are presented in curve form.

Moreover, the use of plain charts has advantages with respect to space requirements. Nomographs if reduced for publication requirements present difficulties in the use of a straight edge with resultant loss of accuracy.

Incidentally for practical calculations of springs, I have found the use of a spring slide rule advantageous and like plain charts more convenient than nomographic charts.

—A. M. Wahl


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Metal Processing

By O. W. Boston, professor of metal processing, University of Michigan; published by John Wiley & Sons Inc., New York; 630 *pages,* 6 *by* 9 *inches, clothbound; available through* MACHINE DESIGN, $5.00 *postpaid.*

Consolidation of the author's two-volume *Engineering Shop Practice* with more recent information has resulted in this comprehensive book on modern machine shop practice. Written with authority by one who has had extensive experience in teaching the subject, the book compares favorably with the many others which recent emergency training courses have brought forth. Emphasis is on the fundamental problems of production and the removal and shaping of metal rather than on pure description of machines. While illustrations of modern machine shop equipment are plentiful, descriptive material has been kept as brief as possible, and in many cases the story is told in fine print below the cut itself.

Machinability is dealt with in detail, supported by extensive data from the author's well-known work on cutting forces, power, tool life, chip formation and surface quality as influenced by the properties of the material being machined, the cutting fluid and the tool shape and quality. This information should be of direct use to the engineer engaged in designing for production. Bibliographies at the end of many chapters add to the value of the book as a reference.

□ □ □

Principles of Heat Engineering

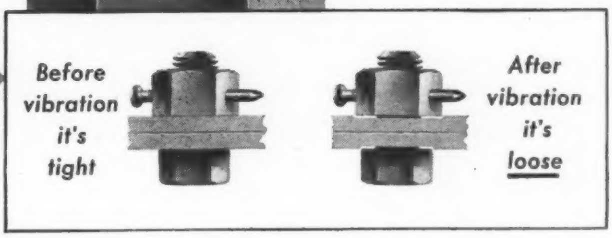
By Neil P. Bailey, Research Laboratory, General Electric Company; published by John Wiley & Sons Inc., New York; 264 *pages,* 6 *by* 9 *inches, clothbound; available through* MACHINE DESIGN, $2.75 *postpaid.*

Basic knowledge of the science of heat, such as is needed by the designer of steam and internal combustion engines, turbines, air compressors, blowers, refrigerating machinery, and allied equipment, is acquired only after arduous study. Too frequently, real physical understanding is obscured by the formidable array of "laws" and mathematical expressions which constitute the subject of thermodynamics. In this book a special effort has been made to give the engineer some comprehension of the physical processes of heat conversion and transfer, as well as the working knowledge needed to solve engineering problems.

Written primarily as a text for engineering courses at college level, the book covers what may be considered the minimum requirement for any engineer today, and can be recommended to practicing engineers desirous of

DRIVE A SPIKE right through both nut and bolt, so the nut can't budge. Now vibrate the assembly just as it would vibrate in ordinary use.

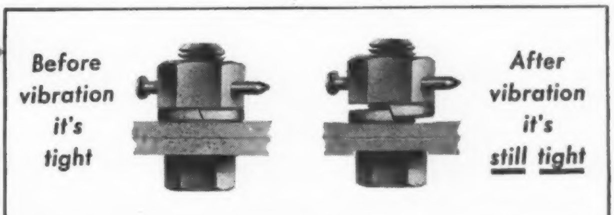
HERE'S WHAT YOU GET



—the nut did not move, but the strain and vibration of metal on metal wore the other parts loose—dangerously loose. Wear by abrasion, and *bolt stretch* etc. *loosen every vibrating part.*

Now keep the spike in but add a strong Kantlink spring washer,—then vibrate it just as you did in the first test!

HERE'S WHAT YOU GET NOW



Yes, still tight, because the strong Kantlink spring reaction held it tight. The Kantlink Spring washer expanded exactly as fast (and as far) as the inevitable *wear tended* to loosen the parts.

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bringing their knowledge up to date. Theoretical treatment is thorough and in every case is pointed toward practical applications of current importance. Logical appreciation of the behavior of gases is aided by frequent use of the kinetic theory of gases.

Beginning with basic concepts, properties of gases, vapors and mixtures, thermal energy, combustion, and heat transfer, the book leads on to discussion of compressors and blowers, internal combustion engines, steam engines, nozzles, turbines, condensers, boilers, power plant cycles, and refrigeration. References and suggested reading lists at the end of each chapter point the way to further study.

□ □ □

Personal Leadership in Industry

By David R. Craig and W. W. Charters; second edition, published by McGraw-Hill Book Co. Inc., New York; 245 pages, 5½ by 8 inches, clothbound; available through Machine Design, *$2.50 postpaid.*

Rapid changes in engineering organizations, due to drafting of executives into government positions or to new plants, have meant rapid promotions of younger men. Responsibility for getting the most out of our limited manpower rests on these young executives, and it is to these, as well as to older men, that this book is addressed.

Written in a highly readable style and enlivened by numerous case histories of personnel problems, the book shows the beginning leader how to get along with subordinates and at the same time improve their work. Typical of the subjects discussed are: Self-training in leadership; forcefulness; prestige of the executive; personal interest in the men; leading without bossing; teamwork; reprimanding; lightening the executive's load; training on the job.

□ □ □

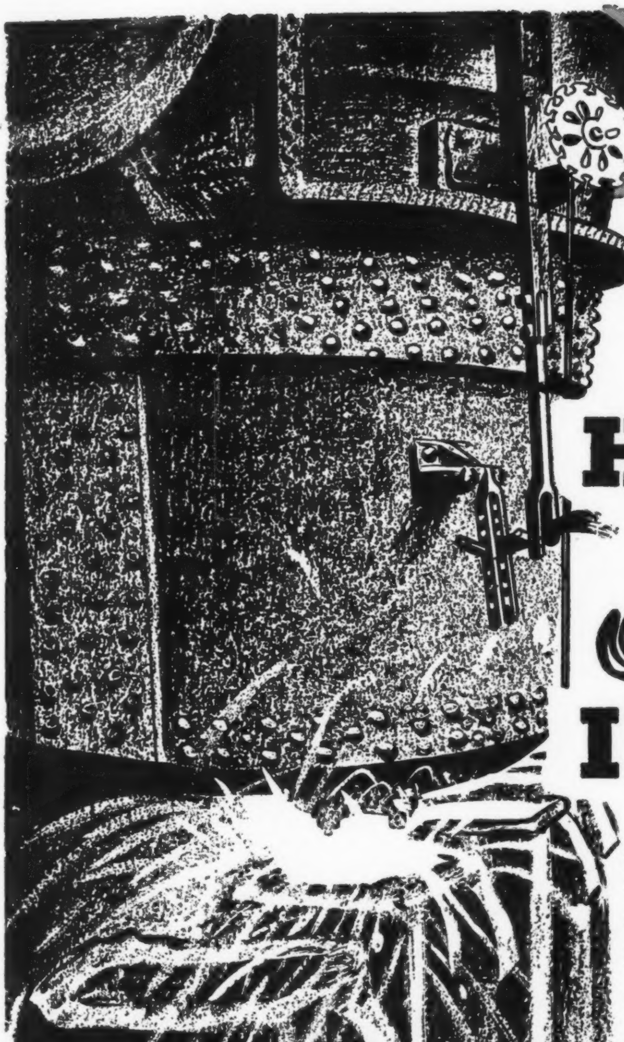
The Steam Locomotive

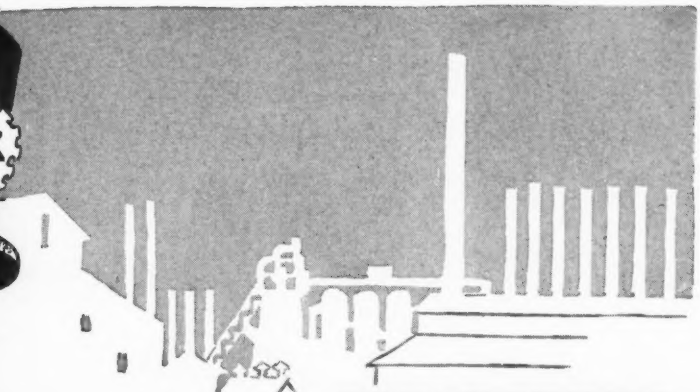
By Ralph P. Johnson, Chief Engineer, The Baldwin Locomotive Works; published by the Simmons-Boardman Publishing Corp., New York; 502 pages, 6 by 9 inches, clothbound; available through Machine Design, *$3.50 postpaid.*

Presenting in convenient form the essentials of steam locomotive design and operation, this book is of particular interest in view of the major role which rail transportation is playing in the war program. Information is given in concise and eminently practical form, free from unnecessary historical matter or academic discussion.

Concerned with broader aspects, the book does not attempt to cover mechanical details. The twenty-six chapters and three appendixes include discussions of fuels and combustion, locomotive design, valve gears, counterbalancing, locomotive testing, high speed trains, and locomotive economics.

An indication of the amount of quantitative informa-





HERE'S WHY Scrap IS SO IMPORTANT!

SCRAP iron or steel turnings, clippings, short ends, worn out or broken tools, spoiled work, idle and obsolete machinery, etc., are valuable as raw materials for remelting in the production of new steel.

Through previous refining, ingredients undesirable in steel have been reduced—thus the use of properly prepared scrap speeds the refining process and enables new steels to be produced more rapidly. Recapture of scrap—from your plant—means opportunity to save time and labor—hence more steel.

Certain scrap contains valuable alloying elements such as nickel, molybdenum, tungsten, etc. which can and must be recovered to augment primary supply to meet tremendously increased demand for constructional and high speed alloy steels for more planes, tanks, guns, ships, tools and machinery essential to the war effort.

To be of maximum immediate assistance, scrap should be segregated by composition wherever possible. Turnings, spoiled work etc. should be identified (SAE, AISI, NE etc. grade number) at the machine where they are generated and so handled as to avoid contamination by waste material or scrap of other types and grades.

The metallurgical experience of our staff is available to aid you in technical phases of metal salvage.

KEEP SCRAP MOVING INTO WAR PRODUCTION!

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

tion given is the fact that there are 70 tables of data and 84 illustrations, mostly curve sheets or line drawings.

Considerable space is devoted to the engineering problems of testing locomotives under service conditions, and a complete set of working drawings for an indicator rig is included in a pocket at the end of the book.

□ □ □

Alloy Constructional Steels

By Herbert J. French and Francis L. Laque, The International Nickel Co. Inc.; published by the American Society for Metals, Cleveland; 294 pages, 6 by 9 inches, clothbound; available through MACHINE DESIGN, *$4.00 postpaid.*

Although much prominence is being given these days to the problems of substituting for alloy steels, more alloy steels are now being used than ever before. This is because there are important properties, vitally needed in fighting machines, which only highly alloyed steels can give. As a comprehensive review of the utilization of alloy steels and as a guide to their selection, this book should be of interest to the engineer as well as to the metallurgist.

Concerned with the so-called "constructional" steels as opposed to tool and die steels, the book covers both unhardened and heat-treated steels, and the effects of alloying elements on behavior at sub-atmospheric and elevated temperatures and on resistance to wear and corrosion. Compositions of the SAE and AISI steels are given in appendixes. Because the book was prepared prior to the appearance of NE steels, these are not discussed. However, some of the low alloy steels for which data are given have compositions closely similar to certain of the NE steels.

□ □ □

Handbook of Ship Calculations, Construction and Operation

By Charles H. Hughes; third edition published by McGraw-Hill Book Co. Inc., New York; 558 pages, 4¾ by 7 inches, flexibly bound in imitation leather; available through MACHINE DESIGN, *$5.00 postpaid.*

For designers accustomed to land practice, whom the fortunes of war have thrown into the marine field, this reference book should prove to be a mine of information. Considerable space is devoted to highlighting the features and characteristics of propelling machinery and auxiliary equipment, constituting a valuable review of the entire field of marine engineering.

In addition to a certain amount of general handbook material, special sections are included covering shipbuilding materials, ship calculations, hull construction, machinery (propelling and auxiliary), electricity, heating, ventilation, refrigeration, air conditioning, bilge, ballast, sanitary and fire protection systems, ship equipment (deck machinery, etc.), and ship operation.

IN OTHER YEARS, production machinery had a comparatively easy time of it—even for this country, birthplace of mass production. But nowadays, plant equipment is subjected to extremely heavy intermittent loads, hums faster than in any peacetime period, without letup.

To keep the nation's war production moving at top speed around the clock, tougher materials had to be developed...many machine parts redesigned. But the only "change" industry required of the Torrington Needle Bearing was its conversion to war production. In the heavy-duty machinery of America-at-war, this unique bearing is again proving its adaptability—in applications where its definite advantages mean more than ever.

Its low coefficient of friction is assuring smooth performance...its high capacity and efficient lubrication are reducing the need for replacement or maintenance attention, enabling management—through steadier production—to turn out greater quantities of war equipment. From the standpoint of the machine builder, the Needle Bearing's small size, saving space and critical materials, and its remarkable ease of installation, cutting assembly time, mean faster delivery of production machinery to wartime assembly lines.

And so it is easy to see why the Needle Bearing was one of the first machine parts to "change over" and why, too—with the war production program increasing in volume and intensity—no further change has been necessary.

IN ADAPTING *the advantages of the Needle Bearing, the experience of Torrington's Engineering Department is at your disposal. Information on capacities and sizes is given in Catalog No. 109. We invite you to write today.*

THE TORRINGTON COMPANY
TORRINGTON, CONN., U. S. A. • *Est. 1866*
Makers of Needle and Ball Bearings
New York Boston Philadelphia Detroit
Cleveland Seattle Chicago Los Angeles
San Francisco Toronto London, England

TORRINGTON NEEDLE BEARING

Every feature fills a wartime need

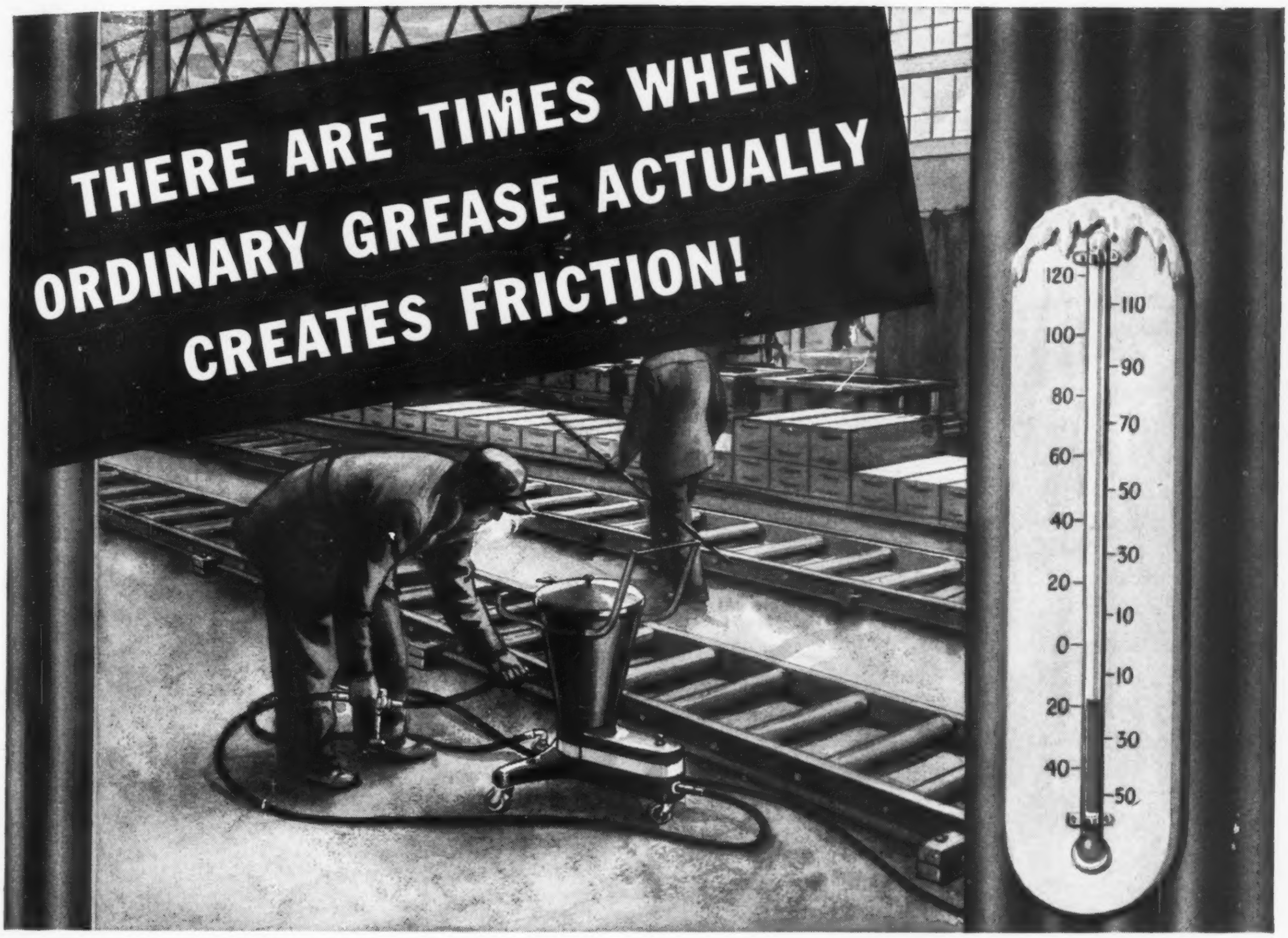
New PARTS AND MATERIALS

Three-Way Valve Redesigned

COMPLETELY redesigned, a three-way magnetic valve which includes both larger iron pipe sizes and port sizes has been announced by General Controls Co., 801 Allen avenue, Glendale, Calif. Designated as series W-33-3, -4, -5, the valves are capable of handling oil, water, air, gas, steam, refrigerants and similar fluids and vapors not corrosive to valve material up to 400 degrees Fahr., with I.P.S. sizes up to 1 inch and port sizes to 15/32-inch. Used for control of fluids to piston and diaphragm operators on valves, doors and gates, as well as for applications where fluids must be distributed from a common source, for pneumatic pumping or for selection of fluid sources, the valve is of single magnetic type and cannot assume an intermediate position. That is, when port No. 1 is open to the flow, port No. 2 is closed when current is on; when current is off, the latter port is open to the flow and port No. 1 is closed. Construction of valve is such that if reverse action is desired it is only necessary to change the two connections. This design also permits high-pressure connection to either common, No. 1 or No. 2 ports without affecting valve operation as long as pressures (differential) are held within certain ratings. The valve is available for all commercial voltages in alternating and direct currents.

Indoor Current Transformer

DESIGNED for accurate metering and relaying applications, Westinghouse Electric & Mfg. Co., East Pittsburgh, has announced its new line of type CT indoor current transformers which are designed in accordance with the specifications of the meter and service committees of the Edison Electric institute and the Associated Edison Illuminating companies. Standardized and me-



Alemite "Sub-Zero" Keeps Bearings Safe At Temperatures Down to 40° Below!

THIS winter more machines than ever before must operate at full speed outdoors or in unheated buildings. Ordinary grease can cease to be a lubricant at extreme cold temperatures. In fact, it *actually creates friction.* But bearings can be safeguarded by using Alemite Sub-Zero Lubricant, a semi-fluid designed especially for such use. It meets government specifications types "D" and "F" applying to Class-14 of General Schedule of Supplies, U. S. Treasury Department, also U.S. Army specifications.

This is only one of many Alemite Specialized Lubricants which meet extraordinary conditions. There are those which withstand extreme heat, others which work under water. All are proved by years of successful service to industry. They can help you prolong machine life and maintain uninterrupted production at a time when delays must be avoided.

SEND FOR YOUR COPY!

The Alemite Industrial Lubrication Manual contains specific recommendations for meeting literally hundreds of industrial lubrication problems. Write for your FREE copy today!

Another Product of STEWART WARNER

ALEMITE

REG. U. S. PAT. OFF.

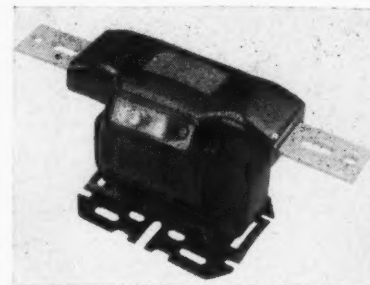
Industrial LUBRICATION

1804 DIVERSEY PARKWAY, CHICAGO, ILLINOIS • BELLEVILLE, ONTARIO

ALEMITE HELPS THE WORLD GO 'ROUND

Ask Anyone in Industry!

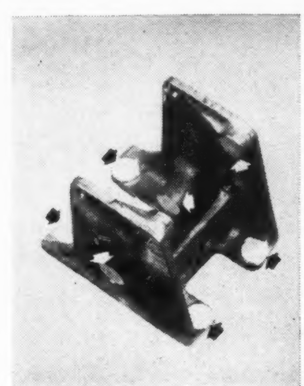
chanically interchangeable with similar transformers of other manufacturers, these units are for 100 per cent current continuous operation without exceeding 55 degrees Cent. temperature rise, and have excellent accuracy at normal currents and also at high short-circuit currents



with heavy relay burdens. Primary and secondary coils are entirely separate and of such construction and assembly that they give maximum mechanical and electrical strength. The size range of the transformers is from 5000 to 15,000 volts at 25 to 60 cycles, with a primary rating of from 5 to 800 amperes.

New Method of Masking Offered

FOR normal masking jobs standard Kum-Kleen labels of Avery Adhesives, 451 East Third street, Los Angeles, are particularly effective when the mask area is small. For special applications, sizes and shapes can be made to specifications, in which case a great deal of



time may be saved in having a mask cut to exact requirements. The stickers have a self-adhesive backing and may be easily peeled off after the operation is completed, without scraping or tearing. They may also be applied without moistening to metal, glass, plastic, wood or any smooth surface.

Rubber Substitutes in Strippings

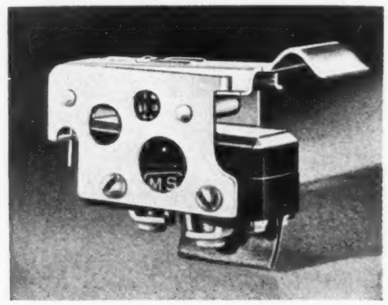
ANOTHER substitute for critical materials formerly utilized in gaskets and strips is a new material with the spongy effect of rubber strip. Introduced by Felt Products Co., 1530 Carroll avenue, Chicago, the Fel-Pro Thiokol strip material is produced by special application of Thiokol to a specially processed felt base, producing the spongy rubber which is weather resistant. Available in lengths over six feet, the material is being used on army


THE ROAD TO "KAMERAD"
IS PAVED WITH SCRAP

vehicles for tailgate moldings, and for numerous industrial applications.

Precision Snap Switch Actuator

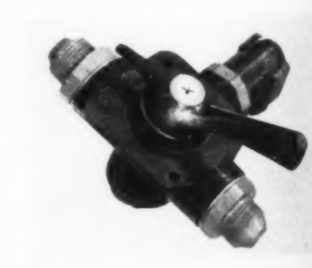
ORIGINALLY brought out for use as a throttle warning switch for aircraft by Micro Switch Corp., Freeport, Ill., Type T actuator is now finding other uses in the machinery field. The metal bracket can be used with any Type Z switch with complete mechanical protection



and less addition of volume and weight. An overtravel of ⅛-inch is provided beyond the point of switch snap by a lever which, at the operating end, is 11/16-inch wide and shaped to slide easily over operating cam and dog. Weight of actuator without switch is 2 ounces. Assembly may be mounted singly or in gang.

Valves Require Little Machining

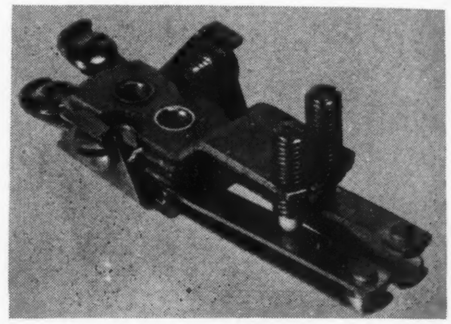
IN PRACTICALLY every military plane now entering service, standard 3-way plug valves produced by the Hydraulic division of Harvill Corp., Los Angeles, are being used to control the directional flow of hydraulic fluid to such apparatus as automatic pilots. The valves are placed in the pressure line ahead of the equipment to be operated by the hydraulic fluid. Formerly of forged stock, the plug valve is produced by the pressure mold casting process as are such parts as the screw plug in the end of the valve. This results in the saving of over 50 per cent in materials required for the valves. Aluminum alloy 13-X is used for all parts except the plug which is pressure-mold cast from manganese bronze. Approximately 83 per cent of the machine tool time required to make each valve is saved, enabling the company to offer quick delivery. The valves are now in large scale production and are available in several styles and sizes.



Two Thermostats in One

ADDED to the line of thermostats built by George Ulanet Co., 92 East Kinney street, Newark, N. J., is a new unit designated as Duplex thermostat of the DSK

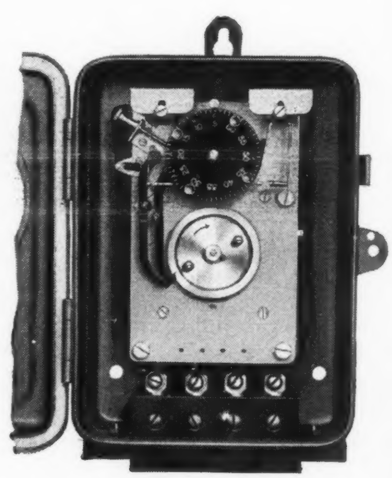
Series. Actually two thermostats in one, stack pile construction permits compactness and sturdiness. The thermostat measures 2⅝ x 1 1/16 x ¾ inches and is easily mounted with two 6/32-inch screws through eyelets having 5/16-inch centers. Temperature ranges are 300, 450 and 700 degrees Fahr. The unit can be connected as two



single-pole, single-throw switches, or as one single-pole, double-throw switch. The recommended electrical rating is 500 watts noninductive load at 115-230 volts alternating current. Three contact combinations are available: Normally closed contacts or normally open contacts on both thermal elements, or normally open contacts on one thermal element and normally closed contacts on the other.

Contact-Making Clock Available

USED in conjunction with maximum demand meters, a new contact-making clock (Type CYC-4) introduced by R. W. Cramer Co. Inc., Centerbrook, Conn., is available in 115-volt, 60-cycle; 220-volt, 60-cycle and 110-volt, 25-cycle types. The clock can also be used as an impulse timer for various time recording instruments where alternating current of commercial frequency is



available. The self-starting motor is of the hysteresis type, operating at 450 revolutions per minute on 60 cycles, and consumes approximately 3 watts. Motor has ample torque to operate the mechanism under the exacting conditions of the intended application. Contacts are of pure silver rated at 1 ampere at 110 volts, alternating current. Standard setting is one-fifth second, and by means of a micrometer screw is easily adjustable if it is desired to change


Magnesium Extruded Shapes
help arm for the BIG squeeze
A SHORT CUT IN
WAR PRODUCTION

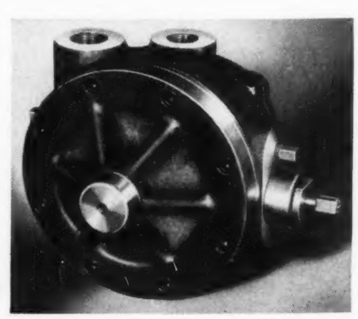
the setting. Once set it will not vary even under vibration. Impulse may be either one, two, three, four, six or twelve per hour. Housing of the clock is pressed steel. A hinged cover with a dust-proof fabric gasket is provided with a sealing screw for wire seal. Adapter and terminal block fit standard meter trim.

Solid Rectangular Contacts

PRESSED steel rheostats with solid rectangular contacts, announced by Ward Leonard Electric Co., Mount Vernon, N. Y., have been developed to attain a finer degree of control in electrically operated equipment. On occasion these rheostats can be used on applications which would otherwise require interpolating rheostats. Rectangular contacts are available in small and large sizes. Small contacts can be furnished on 13-inch or smaller rheostats, and the larger ones on 8-inch or larger rheostat sizes. The selection of large or small rectangular contacts depends upon requirements. For most applications small contacts are adequate. Where the rheostat is required to handle high-capacity currents, large contacts should be specified. Contacts are solid metal, while the contact shoe is a copper-graphite composition and is renewable. Rheostats are available with complete enclosures, with fittings for conduit connections, and with accessories for floor, back-of-board and concentric mounting. Fixed and adjustable stops to protect control equipment can also be provided.

Variable Delivery Pump Redesigned

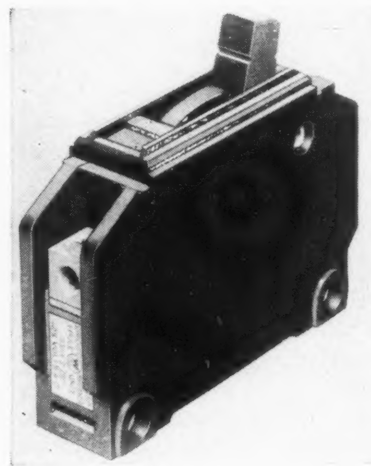
FEATURES of the newly redesigned vane-type, variable delivery pump of Hydra-Motive Inc., 253 St. Aubin avenue, Detroit, include heavier section reinforcing webs, conical instead of flat cover plate for increased resistance to shock, and mounting bracket of a type considered standard on hydraulic pumps. This pump was originally designed for use with an automatic precision-type machine tool control which required high-pressure delivery at extremely low volume. Delivery is variable from 0 to 4 gallons per minute and operating pressures are 1000 pounds per



square inch with a top "short-interval maximum" of 3500 pounds per square inch. Balancing the individual vanes is an additional feature which is exclusive with this pump. Being beveled on two edges as well as on outer side, reduction in wear, elimination of overheating and an increase in operating efficiency is noticed. A split stator instead of the conventional solid ring is employed to permit maximum selection of adjustment. On the outside of the housing, adjustment and limit screws allow for varying delivery to any required amount within operating range.

Breaker Offers Faster Action

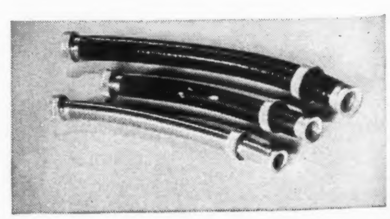
DESIGNED to give practical circuit protection for all kinds of lighting and fractional motors, a new breaker announced by Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., will give adequate protection for all portable tools and appliances. The breaker offers



faster opening action on short circuits and full time delay on overloads. It combines in a single unit a co-operative thermal-magnet trip action, and is available in ratings of 15, 20, 25 and 35 amperes, single pole only, 125 volts alternating current.

Conduit Is Plastic-Covered

FLEXIBLE, plastic-covered conduits known as Amerflex have been announced by Searle Aero Industries Inc., Orange, Calif. These conduits with their plastic coverings instead of rubber for insulation have a reduction in weight which is an important factor in airplane

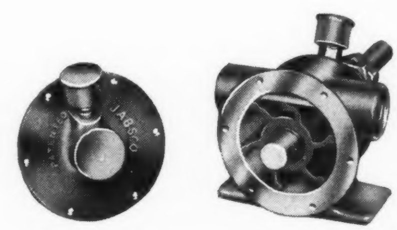


application. Principally used in planes, tanks and boats to protect the electrical assembly from gasoline and oil, the conduit and inside wires are protected by the plastic skin against wear, abrasion, heat and most solvents, including gasoline and oil. Because of the flexibility, tough-

ness and resistance of the plastic, the conduit has a long life. Three different types of coverings are available. One is a transparent plastic which does not become brittle at sub-zero temperatures and through which the metal structure is clearly visible; another is Irv-O-Lite XTE-30 which has high dielectric and tensile strengths and is available in six different colors; and the third is a glossy, opaque plastic which resists brittleness at sub-zero temperatures, also obtainable in six colors. This conduit is made in sizes from 3/16-inch to 1¼ inches inside diameter.

Self-Priming Pump Announced

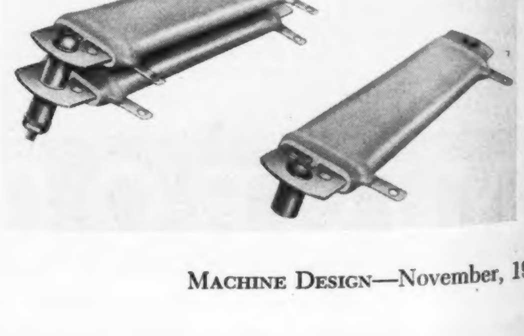
HAVING but one moving part, a new type of self-priming pump has been developed by Jabsco Pump Co., 8302 Wilshire boulevard, Beverly Hills, Calif. It is designed to pump either thick or thin coolants and is recommended for handling coolants that may be contaminated with abrasives. Simple in construction and operation, the only moving part is a single synthetic rubber impeller. Pumping action is positive, and priming each time the machine is started is not required. Impeller fits inside pump



housing and creates a near vacuum. All parts, except the impeller, are of bronze. The impeller being of synthetic rubber permits a certain amount of solids to pass through without clogging or injury. Pump is adaptable where pressure requirements are low, and can be used in milling machines, lathes, tappers and other machine tools. Mounted at any angle it can be operated in either direction, and is available in ¼ to ¾-inch sizes with capacities from 2½ to 22 gallons per minute.

Vitreous Enamel Strip Resistor

STRIP resistors especially suited to aviation and radio applications, and installations where space limitation and high unit space watt ratings are required, have been developed by Ward Leonard Electric Co., Mount Vernon, N. Y. These flat, strip-shaped, wire-wound, vitreous enameled resistors employ a strong, flat refractory for the core with no sharp, angular surfaces, giving a smooth con-



Improve machine performance for Victory—and whatever may follow. Redesign to increase your use of Timken Bearings.

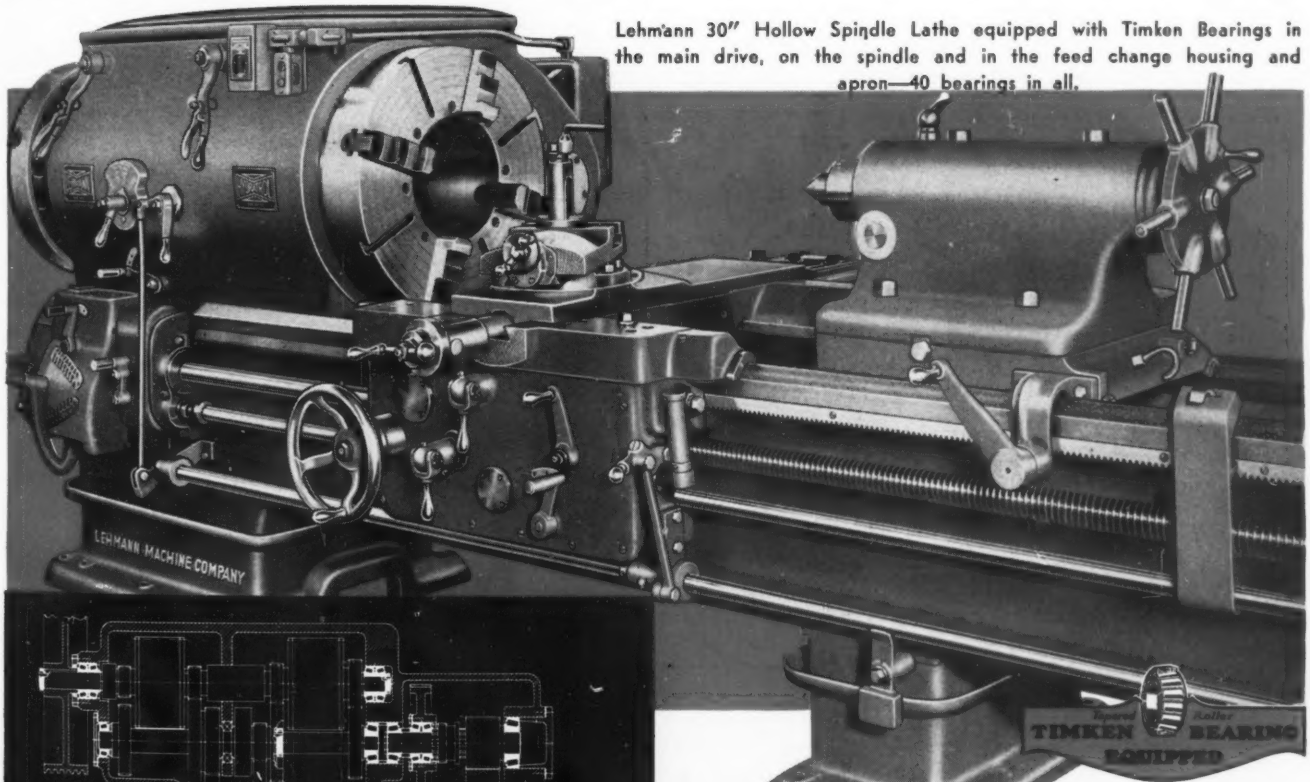
If your equipment already has some Timken Tapered Roller Bearings in it, you know their value. Why not extend it to every suitable bearing point throughout the machine?

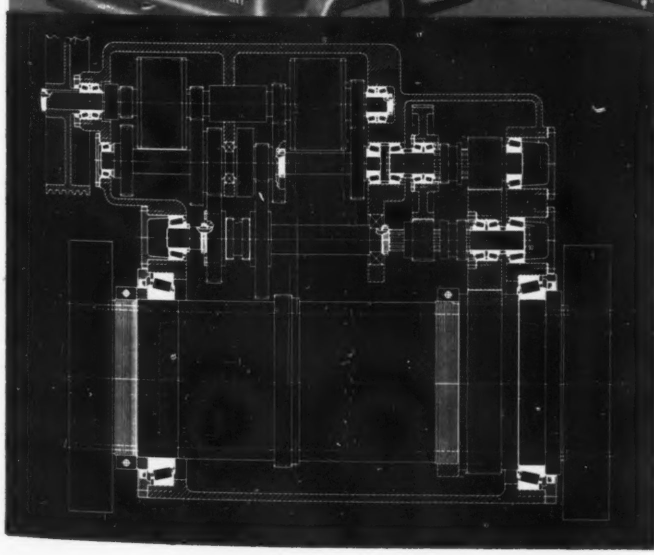
If you are *not* using Timken Bearings at present you don't know what you are missing—in *sales appeal* as well as mechanical efficiency, for "TIMKEN" is the best-known name in bearings wherever civilization exists.

Designing engineers owe it to their employers to see that both of these important advantages are included in the equipment they manufacture.

THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO

Lehmann 30" Hollow Spindle Lathe equipped with Timken Bearings in the main drive, on the spindle and in the feed change housing and apron—40 bearings in all.





Application of Timken Bearings in the main drive, including spindle.

TIMKEN

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TAPERED ROLLER BEARINGS

TO ASSURE VICTORY

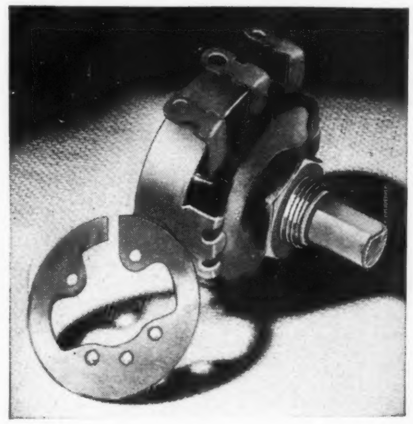
BUY UNITED STATES WAR SAVINGS BONDS & STAMPS

Manufacturers of Timken Tapered Roller Bearings for automobiles, motor trucks, railroad cars and locomotives and all kinds of industrial machinery; Timken Alloy Steels and Carbon and Alloy Seamless Tubing; and Timken Rock Bits.

tinuous form for the resistance wire winding. Terminals are mechanically banded and spot-welded in position on the core; the core and winding then being sealed by a fused on enamel. Each unit is fitted with a self-sustained mounting bracket and spacer. Sizes range from 1½ to 6 inches in length, with ratings of 30 to 75 watts.

Stabilized Element in Controls

DEVELOPMENTS in the processing of resistive coatings have resulted in rheostats and potentiometers claimed to be virtually on a par with wire-wound units in resistance permanence, immunity to climatic conditions and wearing qualities. The Series 37 controls, offered by Clarostat Mfg. Co., 285 North Sixth street, Brooklyn, utilize the new stabilized element which takes the form of a resistive coating on a bakelite base, being practically



as smooth and hard as glass. During processing the element is chemically treated to eliminate all further changes in composition. Likewise it is heat treated to stabilize temperature and humidity characteristics. Reports of reactions of users before the line was introduced brought out the accurate resistance values.

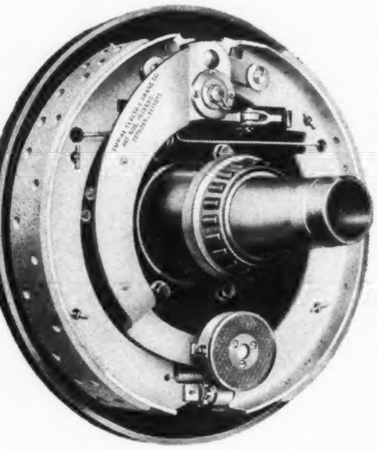
Pumps Are Standardized

COMPLETION of a standardization program on sixteen sizes of the Hele-Shaw fluid power pumps has been made by American Engineering Co., Philadelphia, affecting pumps in both the low and high pressure ranges. This includes pump capacities of .25, .4, .75, 1.5, 3, 6, 9, 12 and 18 in the high pressure series, and of .25, .4, 1.5, 4, 7, 12 and 18 in the low pressure series. The standardization enables the company to increase production and improve deliveries and users to simplify their layouts and speed up production of power-operated equipment. The company has also standardized its pump controls, reducing the number of sizes and increasing their applications to a greater number of pumps.

Electric Brake Is Offered

RECENTLY developed by Empire Electric Brake Co., 118 South Fourteenth street, Newark, N. J., the Magdraulic electric brake consists of a backing plate, a brake shoe mechanism, a lever, an electromagnet, and

an armature plate, all housed within the brake drum. Armature disk, a circular flat steel plate, is secured to the brake drum which rotates with it. Electromagnet is supported on end of lever and is in light contact with the armature plate. The lever is pivoted at a point between the ends of the brake shoes. When controller is depressed an electric current flows through the electromagnet. The attraction and friction of the facing of electromagnet on

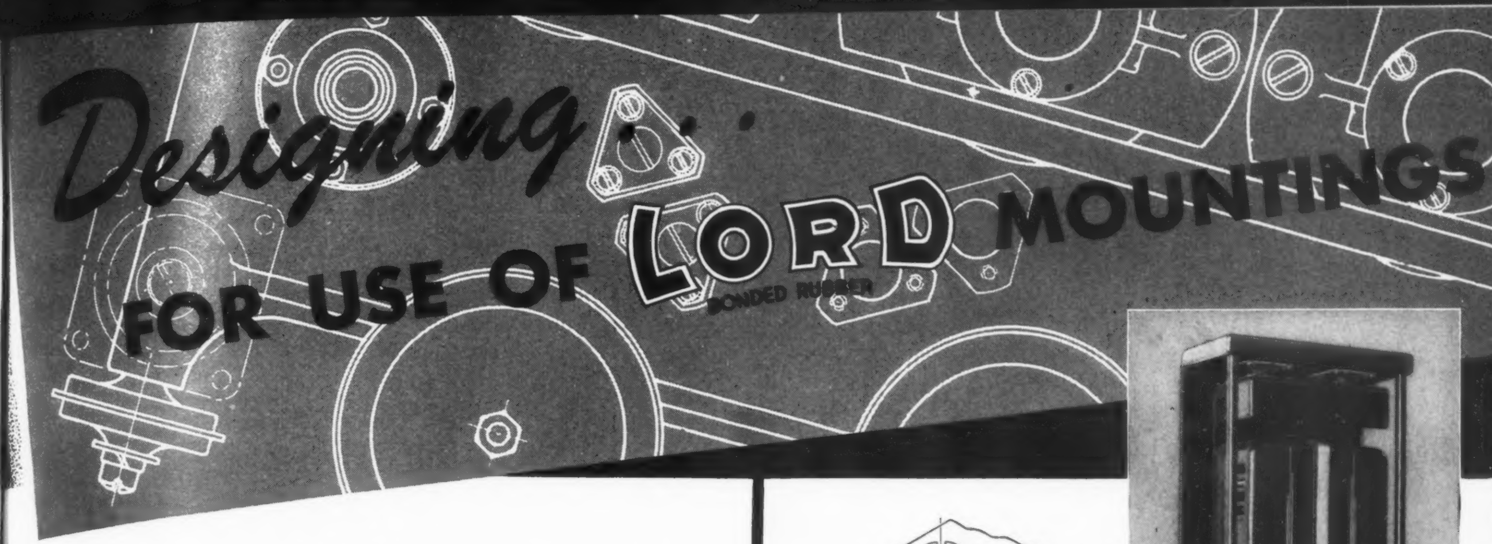


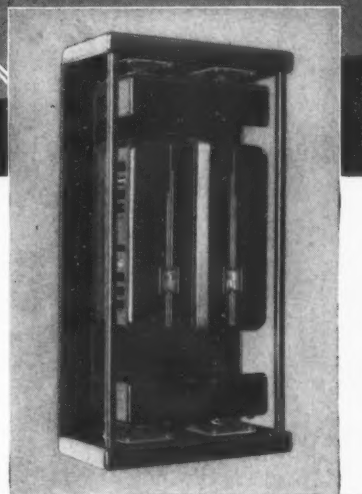
the armature disk causes lever to move in direction of rotation of the wheel in which armature disk is turning. Friction force at the end of lever multiplied by lever ratio causes the lever pin, fixed to the pivoted lever, to expand the brake shoe by moving shoe link, thus exerting a retarding effect. This effect is proportional to flow of current through the electromagnet. Small currents give a light and smooth brake action while heavier ones cause more powerful, smooth braking action.

Fastener for High Tension Loads

TO MEET the critical stresses being developed at higher speeds in the aircraft field, Nigg Engineering Co., Covina, Calif., has built a new cowl fastener which will withstand unusually high shear and tension loads,

yet is instantly locked or unlocked. Tests show that the fasteners will withstand an ultimate tension load of 1600 pounds average, or approximately 50 per cent greater than AN specifications. Ultimate shear loads average 2700 pounds, or approximately 250 per cent in excess of





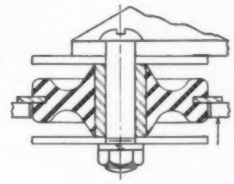
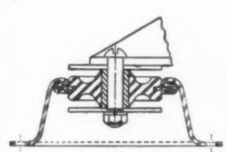
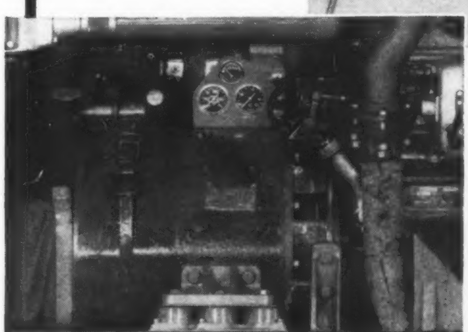
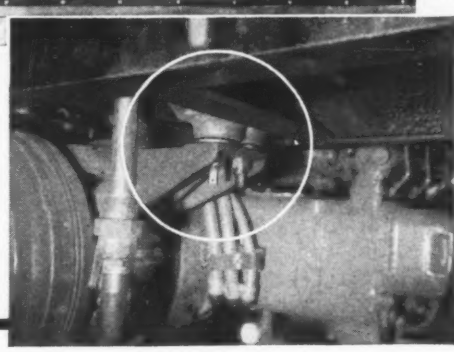


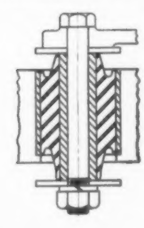
PLATE FORM MOUNTING



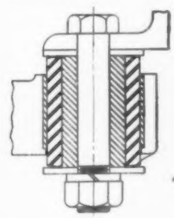
HOLDER TYPE MOUNTING







TUBE FORM MOUNTING



VERTICAL SNUBBIN[G] MOUNTING

Incorporate Lord Shear Type Mountings in your new equipment designs, regardless of type or size, light and delicate or heavy and massive. The advantages to be gained are numerous and the results are permanent. Lord Bonded Rubber Shear Type Mountings isolate vibration, absorb shock and minimize all noise translated through solid conduction. Providing for Lord Mountings in your equipment designs allows you to enjoy many advantages of a far reaching, economic character, resulting in *immediate* lower production costs, as well as lower *ultimate* cost of equipment. Lord Bonded Rubber Mountings are made in two main types, Tube Form and Plate Form, with variations to suit special conditions. No intricate layout, no special tooling or close machining are necessary to accommodate Lord Mountings.

For Plate Form Mountings, simply provide attaching holes and clearance for rubber body. For Tube Form Mountings, provide sockets, solid or clamp type. For Holder Type Mountings, attaching holes only are required. Lord Mountings are made in many standard sizes with load capacities ranging from a few ounces up to 1500 pounds.

Properly installed, Lord Mountings definitely:—

1. *Prolong equipment life* by isolating vibration, which reduces metal fatigue, thereby preventing subsequent failure.

2. *Increase production* by eliminating the necessity for close machining and precision alignment.

3. *Save vital material* by reducing equipment weight; heavy inertia masses of machinery bases can be eliminated.

4. *Increase personnel efficiency* by eliminating nerve wearing noise and vibration, translated through solid conduction.

5. *Lower maintenance costs* by protecting equipment against sudden load shocks and stresses, thereby minimizing repair and replacement operations.

All of the far reaching effects and favorable results that will be obtained by incorporating Lord Bonded Rubber Mountings in your new equipment designs cannot be listed here. Send for Bulletins 103 and 104 on Lord Shear Type Mountings, or better still, call in a Lord vibration engineer for consultation on your design problems. There is no obligation.

See our exhibit at the National Power and Mechanical Engineering Exposition Madison Square Garden, New York, Nov. 30-Dec. 4

LORD MANUFACTURING COMPANY . . . ERIE, PA.

[SA]LES REPRESENTATIVES . . . NEW YORK, 280 Madison Ave. . . . CHICAGO, 520 N. Michigan Ave. . . . BURBANK, CAL., 245 E. Olive Ave.

IT TAKES RUBBER IN SHEAR TO ABSORB VIBRATION

AN specifications. The fastener is not dependent on springs, but locks and unlocks by means of a screw action, producing any desired amount of tension to hold sheets together. This provides an adjustment accommodating an unusually wide variance of sheet thicknesses for each given size of fastener. Fewer stock sizes are therefore necessary to accommodate all standard airplane requirements. The fastener is also equipped with an indicator on the face which shows the exact position of the locking member of the stud.

V-Belts for Vehicle Motors

ESPECIALLY adapted for motors of tanks and armored vehicles, Goodyear Tire & Rubber Co., Akron, O., has announced a new type of V-belt which utilizes steel wires instead of the conventional fabric or cord carcass. Increased strength, higher resistance to heat and far less stretch are provided in the new belts, factors important because of inaccessibility of fan belts and the amount of heat developed by powerful motors in armored vehicles. With development of the new endless steel-wire belt and its greater strength, the field of multidrives on a single belt undoubtedly will be extended, according to the company's engineers. This would mean, in the case of vehicle motors, more engine parts on a single belt in addition to the fan and generator. The belts also can be adapted for industrial uses on heavy-duty drives. The same principle has already been adapted to conveyor belting.

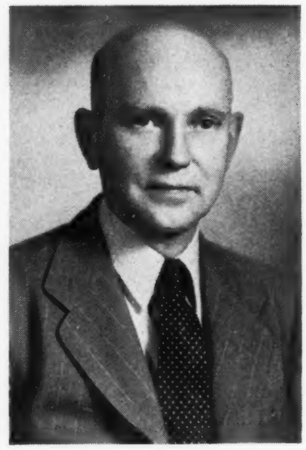
Valves Control Fluid Flow

TO RETARD the rate of flow of fluid in one or both directions in a hydraulic system, Bendix Aviation Ltd., North Hollywood, Calif., is offering a simple means of accomplishing desired results with its restrictor valves. Both types of these valves are quickly adjustable under pressure from no flow to the area of ¼-inch tubing. They incorporate needle type valves providing an annular flow passage at the point of restriction, thus reducing possibility of stoppage by foreign matter.

Controls Are Explosionproof

EXPLOSIONPROOF thermostats manufactured by White-Rodgers Electric Co., 1209 Cass avenue, St. Louis, are line-voltage, hydraulic-action controls for heating, air conditioning and refrigerating applications where hazardous conditions exist. They are particularly recommended for oil refineries, equipment in munitions plants, cleaning plants and similar locations. The thermostats are available in self-contained and remote bulb types. The first is for controlling temperatures of large air spaces while the latter is for controlling temperatures in ducts, walk-in coolers, liquid baths and similar applications. An external knob or tamperproof internal adjustment is available in both fixed and variable differential types. The semisteel case is approved by Underwriters' Laboratories. It is tapped for ½-inch conduit fitting and is finished in black, baked crackle enamel. All standard ranges to cover any type of application are available in these controls.

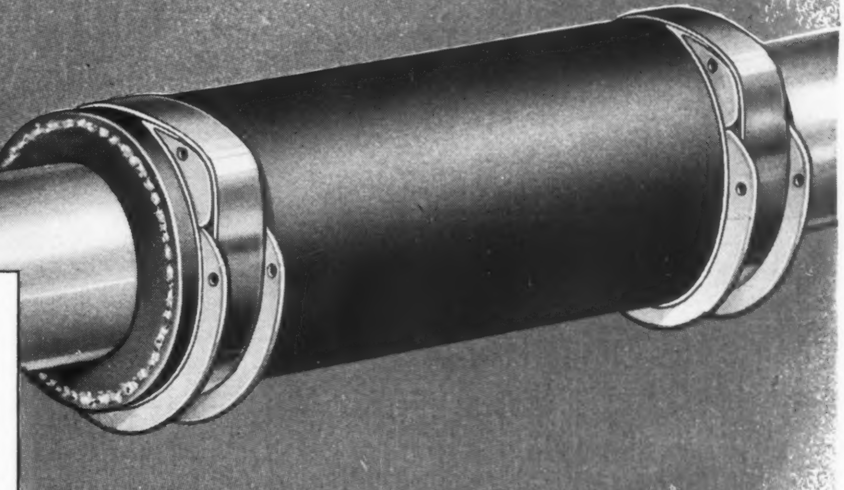
MEN OF MACHINES

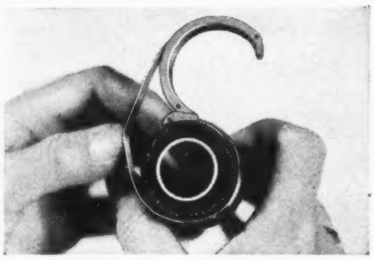


WELL known in the machine tool industry as a machine designer and hydraulic engineer, Racy D. Bennett has joined the engineering staff of the Vinco Corp., Detroit, builders of gages and machine tools. His new title is that of development engineer. For the past two years Mr. Bennett has operated an engineering and consultant service. Previous to this position he was connected for five years with Ex-Cello Corp., Detroit, where he was engaged in the design of machine tools and development of the company's packaging machines. Mr. Bennett has also been associated with other companies in similar positions. Some of these are the Buick Motor division of General Motors Corp., Kraetke Brothers, and Snyder Tool & Engineering Co. He is, therefore, well fitted to perform the duties of his new position as development engineer of the Vinco Corp.

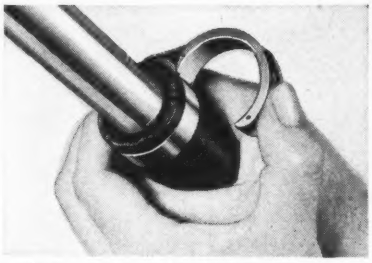
CONSIDERable design experience in the aircraft field has enabled Raymond H. Rice to reach the top of the ladder in this industry in his recent appointment as vice president in charge of engineering of North American Aviation Inc. Born in Amarillo, Texas in 1904, Mr. Rice received his degree of bachelor of science in mechanical engineering from the University of California. After graduation, he joined the Army Aircraft branch at Wright Field as junior engineer where he remained for one year. He then became affiliated with Glenn L. Martin Co. in charge of structural design, and worked on the first China Clipper and early Martin B-26 bombers. In 1935 he joined the North American Avia-

Service Simplicity

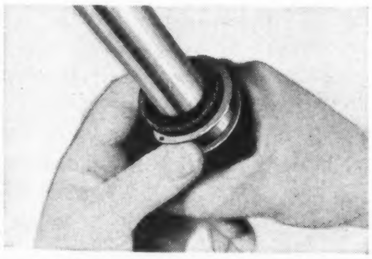




1. Quick and Easy to use. Just place open clamp around the hose.



2. Then swing the locking latch to closing position. No tools are needed!

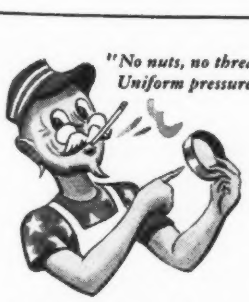


3. Result—a hose clamp which exerts even pressure all around!

ADEL
STA-LOC HOSE CLAMP

At last, a *service-designed* hose clamp which can be re-used any number of times without fracture or loss of time! *Design Simplicity* has done away with nuts, threads and pivots. Fewer parts permit substantial reduction in stores. No special tools or wrenches are required, no special skill. A simple adjustment . . . and they snap securely into place with a tight grip that is *uniform all around*. No bulges, bends or concentrated stresses due to focal locking pressure. Made of stainless steel for speedy assembly, long service life, and continued re-use. War industry executives may obtain complete information by contacting the Huntington Division or nearest engineering service office.

"No nuts, no threads—Uniform pressure ALL around."



HUNTINGTON
PRECISION PRODUCTS

Division of ADEL PRECISION PRODUCTS CORP.

ENGINEERING SERVICE OFFICES—1444 Washington Ave., Huntington, W. Va.; Administration Bldg., Love Field, Dallas, Tex.; 609 Stephenson Bldg., Detroit, Michigan; 303 Wareham Bldg., Hagerstown, Maryland; 302 Bay Street, Toronto, Ontario, Canada

tion Inc., where he was again placed in charge of structural design. Since that date he has been chief of design and assistant chief engineer for the company. Early in 1939 he was made chief engineer, succeeding J. L. Atwood who became vice president. Mr. Rice held the position of chief engineer until recently when he was made vice president in charge of engineering for the organization.

♦

S. J. Benn, previously employed as mechanical engineer at Brunner Mfg. Co., has been appointed chief engineer of Globe Hoist Co., Philadelphia. Mr. Benn has also been connected with Merchant & Evans Co., Philadelphia, as chief engineer.

♦

Newly nominated president of the Society of Automotive Engineers is Mac Short, vice president in charge of engineering, Vega Aircraft Corp. One of the organizers of this company, a subsidiary of Lockheed, Mr. Short has become recognized as an outstanding aeronautical engineering executive. Born on Christmas Day in 1897 in Kansas, he entered the U. S. Army Air service in 1917 at the age of 19. Retiring from active duty as a flying lieutenant at the end of the war, he earned his way through Kansas State Agricultural college, flying over week ends and through the summer months. Receiving his mechanical engineering degree in 1922, he re-entered the Army service at McCook Field, Dayton, O., as a junior aeronautical engineer. From 1925 to 1927 he worked for his Master's degree while instructing in aeronautical engineering at Massachusetts Institute of Technology. During the next ten years he was vice president and chief engineer of Stearman Aircraft Co., Wichita, Kans., a company he was also instrumental in forming. In 1937 he organized and became president of Vega, but in 1940 he relinquished administrative duties to devote his time to engineering and furtherance of the company's aircraft. Mr. Short has long been a member of the Society of Automotive Engineers, and a leader in many of its activities. In 1934 and 1941 he was national vice president for aircraft activities of the society and in 1940-41 became chairman of the southern California section.

♦

William T. Hedlund, formerly vice president in charge of engineering of Electrolux Corp., has been appointed president of Elastic Stop Nut Corp., Union, N. J.

♦

John S. Chafee, vice president of Brown & Sharpe Mfg. Co., is the new president of the Machine Tool

(Concluded on Page 134)

INDUSTRY SHOOTS PRODUCTION MINUTES

★ save time
★ save metal
★ save cost
★ improve quality
WITH MICROHONING

Micromatic Hones have lowered the time required for final sizing and surface finishing operations from days and hours to minutes and seconds.

Microhoning saves TIME—COST—METAL REMOVAL—MANUFACTURING COST—AND IMPROVES PRODUCT QUALITY which combined means more target hits in the tough service of WAR.

Micromatic Hones range from sizes for bores .303″ to 25½″ in diameter—from ¼″ to 900″ long. They generate geometrical and dimensional accuracy, uniform size and any desired surface finish with minimum removal of stock.

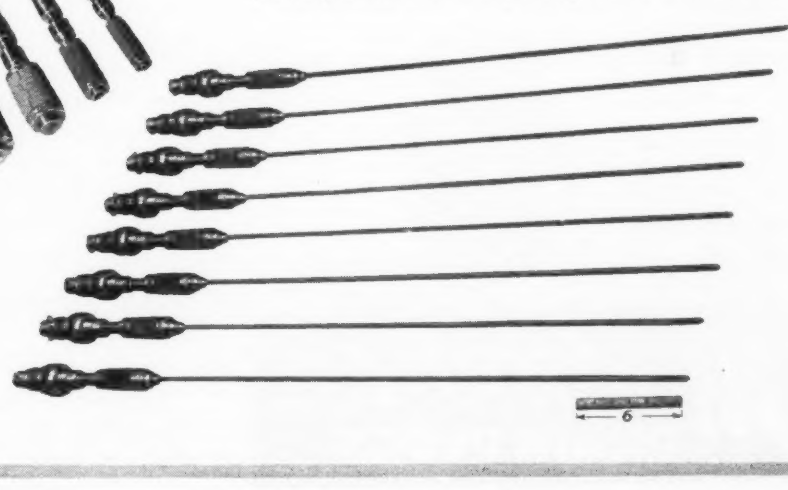
MICROMATIC HONE CORPORATION

1345 E. MILWAUKEE AVE. MICRO MATIC **DETROIT, MICHIGAN**

DIESEL • • • —
24″ Microhone for Diesel engine liners. Extra miles per hone in submarines, mine sweepers and similar marine engines require the controlled accuracy provided by Microhoning.

ORDNANCE • • • —
Draw Finish Microhones. These provide a finish in recoil chamber and other bores with all machining marks co-directional with the axis of the bore. Simulating a mechanical wearing in process—this type of honing shortens or eliminates "wearing in" in service.

ORDNANCE • • • —
Rifle barrel Microhones for .303″ bore have speeded and improved precision rifle making throughout the allied nations.



The use of Microhoning is expanding rapidly. Let us send you literature on latest developments.

(*Concluded from Page* 128)

Builders' association which recently held its annual meeting. WALTER W. TANGEMAN, vice president of Cincinnati Milling Machine Co., has been elected first vice president; FRED H. CHAPIN, president of National Acme Co., as second vice president; and DAVID AYR, president of Hendey Machine Co., as treasurer.

♦

ROBERT C. SESSIONS, who has been connected with Sessions & Sessions, Cleveland, consulting engineers, has been appointed chief engineer of The Brown Fintube Co., Elyria, O. Before entering consulting work, Mr. Sessions was for some time in charge of the engineering and experimental division of Steel & Tubes Inc.

♦

ROBERT M. KALB has been appointed chief engineer of Kellogg Switchboard & Supply Co., now engaged in producing war communication apparatus for the nation's armed forces. Mr. Kalb is a telephone research engineer of long experience and was previously assistant chief engineer of the company. B. A. WALLACE, associated with the company's laboratory and engineering department for many years, has been promoted to the position of assistant chief engineer.

♦

ARTHUR M. HOUSER, engineer of standardization for the Crane Co., Chicago, has been made a consultant in the Simplification Branch of the Bureau of Industrial Conservation of the War Production Board.

♦

JACK E. PICCARDO, consulting hydraulic engineer, formerly chief engineer with Jacuzzi Bros. Inc., Berkeley, Calif., has been appointed mechanical engineer (production) in the San Francisco Ordnance District of the United States War Department.

♦

WILLIAM B. STOUT, president of Stout Engineering Laboratories Inc., has been added to the special board of consultants of the Smaller War Plants Corp.

♦

ROBERT P. BREESE has joined General Bronze Corp., Long Island City, N. Y., as industrial development engineer. He formerly was connected with the Bendix Products division of Bendix Aviation Corp.

♦

EMIL HEMMING JR., ROBERT GOLDSMITH, formerly of the University of Nebraska, and WILLIAM RENWICK of New York, recently graduated from the Plastics Industries Technical Institute and received civil service appointments as junior plastics technologists at the Naval Aircraft Factory, Philadelphia. Research and development work in the applications of plastics for aircraft are centered at the Philadelphia plant.

♦

W. H. HOLCOMB has been appointed assistant to the executive vice president of Baldwin Locomotive Works, Philadelphia. Mr. Holcomb since June 1939 has been vice president and general manager of Pelton Water Wheel Co.

♦

LESTER M. GOLDSMITH, chief engineer of Atlantic Refining Co., has been awarded the honorary degree of doctor of science by Drexel Institute of Technology.

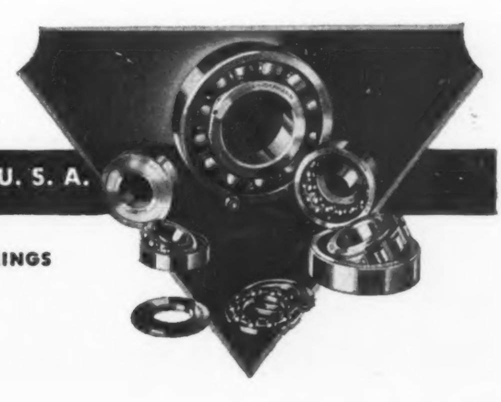
YOUR MACHINE EQUIPMENT

A treacherous, insidious saboteur lurks in every plant engaged in war production, alert to every opportunity to damage your machines and curtail your output. FRICTION is his name, and your only safeguard against him is the vigilant protection of F.B.I.—FREQUENT BEARING INSPECTION.

Keep all bearings clean and well lubricated. Exclude dust, dirt and moisture. Use only high-grade lubricants. Watch for the first signs of unusual heat or noise or looseness in the bearings. If possible, keep replacement bearings at hand, for a quick substitution if needed. America, in her vast war program, cannot afford to lose a single machine-hour of production. Guard against such losses by FREQUENT BEARING INSPECTION.

We will gladly cooperate with you in maintaining or increasing your production—by experienced counsel on the use and care of anti-friction bearings, and by supplying you, wherever possible, NORMA-HOFFMANN PRECISION BEARINGS for replacements.

Write for the Catalog. Let our engineers work with you.



NORMA-HOFFMANN BEARINGS CORP'N., STAMFORD, CONN., U. S. A.
FOUNDED 1911

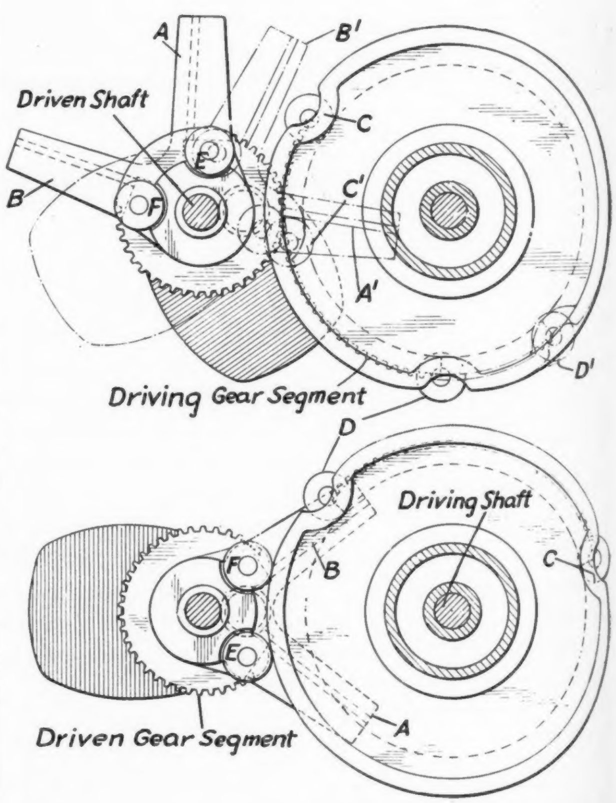
PRECISION BALL, ROLLER AND THRUST BEARINGS

NOTEWORTHY PATENTS

Provides Intermittent Drive

AN INTERMITTENT drive mechanism, suitable for such operations as automatic feeding of successive blanks into a press, is covered by a patent recently assigned to The Sheridan Iron Works. The mechanism permits the incorporation of a time cycle consisting of four phases: Acceleration, constant speed, deceleration, and dwell, the relative duration of these phases being under the complete control of the designer.

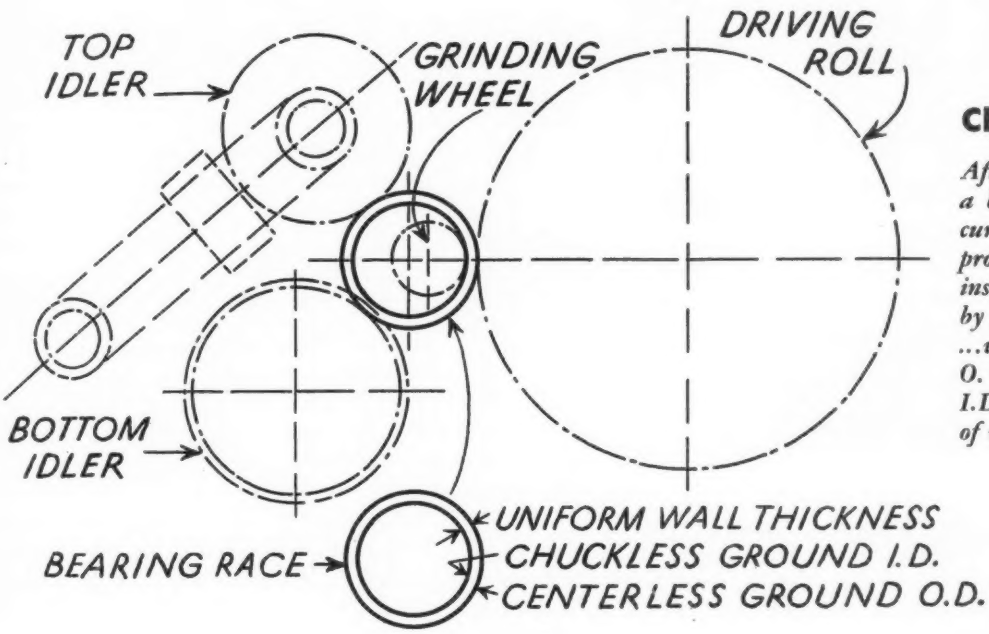
In the position shown in the upper illustration, the driving gear segment is meshed with the driven gear segment, this being the constant velocity phase. The driven shaft speed during this phase is higher than the driving shaft



Upper diagram shows mechanism in position of maximum driven shaft speed; lower shows position at end of dwell

speed. As the mechanism rotates into the position indicated by the broken lines, the arm *A* on the driven shaft makes contact with the roller *C* on the driving wheel (*A'* and *C'*). The driven element slows down as rotation continues beyond this point and stops in the position indicated in the lower illustration. During this deceleration period

Hyatt's Gift To Industry Ten Years Ago Is Helping To Win The War Today!



INTERNAL GRINDING
Chuckless Method

After the outside diameter of a bearing race has been accurately ground by our improved centerless method, the inside diameter is controlled by our own chuckless method ...which utilizes finished race O. D. to produce concentric I. D. with absolute uniformity of wall thickness.

CHUCKLESS GRINDING is helping to speed up America's war effort...make precision manufacture possible at a mass production pace . . . and avoid material waste.

This entirely new grinding method was invented by Hyatt nearly twenty years ago. Our races have been produced by this precision process ever since.

Later, this great advance in grinding technique was made available to all industry.

Therefore, in addition to helping us make more and better Hyatt Roller Bearings for war machines, this gift from Hyatt helps other vital plants speed the day of an ultimate American victory.

Hyatt Bearings Division,
General Motors Corporation,
Harrison, N.J., San Francisco,
Chicago, Detroit, Pittsburgh.

THE 50TH YEAR OF **HYATT ROLLER BEARINGS**

the roller E makes contact with the periphery of the driving wheel, rolling into and out of the recess provided for this purpose.

At the end of this deceleration period the two arms A and B are symmetrically disposed about the line joining the centers of the driving and driven shafts, as shown in the lower illustration, with the rollers E and F bearing against the rim of the driving wheel. This permits the driving wheel to continue rotating but locks the driven wheel, preventing drift during the dwell period.

At the end of the dwell period, lower illustration, the roller, D engages the arm B, imparting rotation to the driven shaft at an increasing rate as the effective radius of contact diminishes. At the end of this acceleration period the velocity is maximum and at this point the gear segments engage, the rotation then continuing at constant velocity. Engagement is smooth because the pitch circle radius of the driven gear segment is equal to the effective radius of the arm B at the moment of engagement.

Positive Action Insured

To permit the driven shaft to rotate into and out of the dwell position, two recesses are provided in the circumference of the driving wheel, into which the rollers E and F slip during the deceleration and acceleration phases respectively. Correct profile of the rim engaging the rollers E and F as they approach and leave the recesses insures positive action regardless of speed and load, preventing overrunning during acceleration and lagging during deceleration.

While the intermittent drive described furnishes the desired time ratios for the cycle, it is often desired to modify the motion to give a smoother acceleration and higher momentary speeds. By interposing a fast-and-slow drive, such as a Whitworth mechanism, between the driven shaft and the final driven unit such modification may be obtained. The faster phase of the Whitworth mechanism is made to coincide with the gear drive and the slower with the deceleration and acceleration of the driven shaft.

Maintains Constant Driven Speed

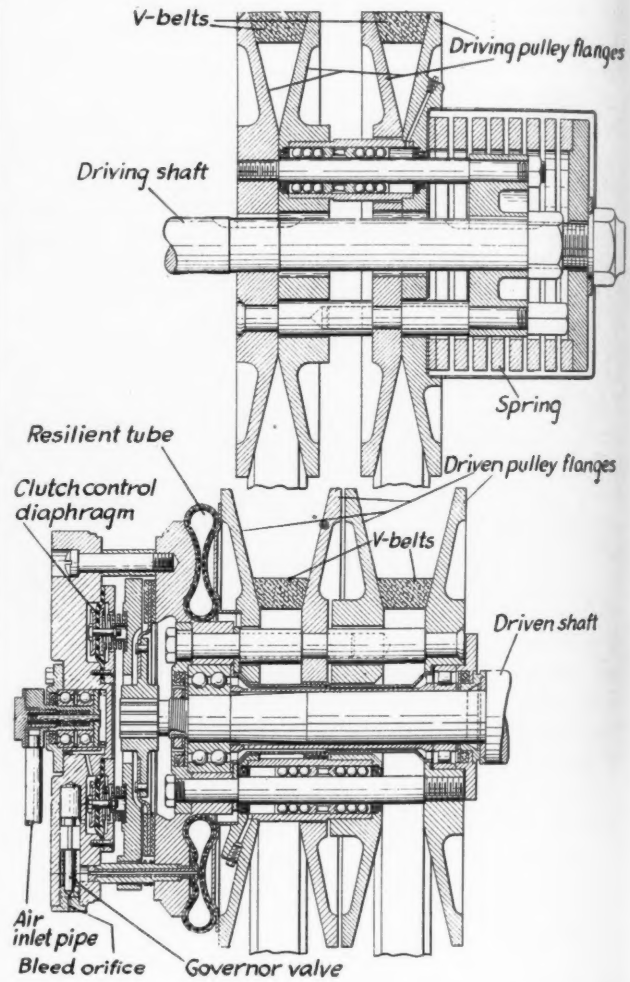
AUXILIARY equipment such as generators and refrigerating compressors on trucks, railroad cars, etc., driven from an axle of the vehicle may operate at substantially constant speed regardless of vehicle speed through the use of a patent assigned to General Motors Corp.

Incorporated in the drive is a pair of variable-ratio V-belt pulleys, the conical flanges of the driving pulleys, upper diagram, being normally held together by a spring so that the belts ride at the maximum radius of the driving and minimum radius of the driven. In this condition, which exists at low driving shaft speeds, the transmission serves as a speed increaser. The illustration on Page 140 shows the mechanism in this condition.

The driven pulleys, lower diagram, are free to rotate on bearings mounted on the driven shaft, and are connected to the shaft through a friction plate clutch operated by air pressure. When the driven equipment is to be operated, air is admitted through the pipe shown at left of the lower illustration and flows through drilled

passages to the spaces behind the clutch-operating diaphragms, thus engaging the clutch and causing the driven shaft to rotate with the pulley.

Speed regulation is effected by means of a centrifugal governor control valve rotating with the pulleys. A spring holds the valve towards its innermost or open position, allowing air to bleed past the valve to the atmosphere. Centrifugal force, as the driven pulley speed increases, acts to move the valve outward, partly or completely clos-



Inflation of resilient tube presses driven pulley flanges together, causing belts to ride on the outer radius of this pulley and on the inner radius of the other

ing the outlet. Pressure thus builds up behind the valve and in the resilient tire tube, which is connected with the space behind the valve. Resulting inflation of the tube presses the pulley flanges together, wedging the belts toward the outer radius. Increased belt tension forces the flanges of the driving pulley apart a corresponding amount, thus permitting the driving pulleys to rotate faster in relation to the driven. If the speed drops, the governor valve returns to the open position, allowing the tube to deflate through the needle valve and the belts to return toward the initial position. For a constant driving speed the governor valve seeks an equilibrium position in which escaping air maintains the tube in a partly-inflated position corresponding to the speed ratio required at the particular driving speed.

DESIGN ABSTRACTS

Standardization and the Liberty Ship

LIBERTY ships were an outgrowth of certain other ships ordered in this country by the British government. The type of ship selected is known as the North East Coast tramp. This particular type of vessel has for the last forty years carried the bulk of the world's cargoes, but in some ways it bears the same relation to a modern cargo carrier as the Model "T" Ford bears to a modern automobile.

We in America have developed cargo vessels fully the equal of anything abroad, and the British themselves have made considerable improvements in machinery for cargo vessels, so we felt surprised at the type of machinery selected—reciprocating steam engines—and we were not at all sure that we could find builders to manufacture machinery of a type almost abandoned here. Another step which appeared to be backward was the use of coal-burning, hand-fired Scotch boilers. However, in view of the results obtained, there can be hardly any question as to the wisdom of sticking to a simple type of vessel.

Shortly after the British ships were contracted for, the U. S. Maritime Commission decided to build a large number of what were then called "Ugly Ducklings" but are now generally referred to as Liberty ships. While these ships are generally of a type similar to the British ships, many changes were made, most important of which were the use of oil as fuel and water tube boilers instead of Scotch boilers. These two features were undoubtedly improvements, but the difficulty now arose that, once started, the tendency to change the design so as to "improve" it became almost an avalanche.

Changes Not Necessarily Improvements!

It took courage in the face of criticisms to insist on duplication of the British machinery wherever possible. Had another course been followed the changes in minor details would have been legion, although the ultimate result might have been a somewhat more efficient installation. However, where an "improvement" is made in any piece of apparatus that functions perfectly without this "improvement" we generally get into trouble, and when changes of this type are made they usually involve a great many conferences, and then unless the changes are properly tested out the performance of the entire plant may be marred due to the failure of some small detail.

When the Liberty Ship program got under way contracts were made with about twelve engine companies, each of which was supplied with plans of the engines for the British ships. The first American manufacturer had redrawn and amplified the British plans to suit American practice. As soon as these plans were distributed the fun started all over again, as each manufacturer had practices

that differed somewhat from the others, and correspondence about details took on such tremendous proportions that utter confusion would have resulted had not a conference between all the engine manufacturers and the various interests been called to straighten out details.

Two days of such a conference performed marvels. All difficulties were ironed out and from then on progress was rapid, with a minimum of questions arising. The co-operation of these engine builders with the various authorities and with each other was a most healthy example of what American unity can do when it wishes really to "go to town." What worked in the case of the engines was equally effective in the case of the boilers, auxiliaries, deck machinery and other component parts of the vessel. This co-operative effort bore splendid fruit.

As a result, ships building at many yards today are identical. Many engines, boilers, shafting, propellers and auxiliaries are being swapped all over the country, ships which need engines getting them on time whether they were the engines scheduled for them or not. (*Abstract of talk by H. C. E. Meyer, Chief Engineer, Gibbs & Cox Inc., at the recent S.P.E.E. convention*).

Air Operates Circuit Breakers

COMPRESSED air is being used as a source of energy to close oil circuit breakers, with the advantages that the electrical drain on a battery at the instant of closing is only the control relay current, not the full solenoid closing coil current, and full air pressure is instantly available to start closing the breaker. A solenoid builds up in power at a slower rate, depending on the inductance of the coil.

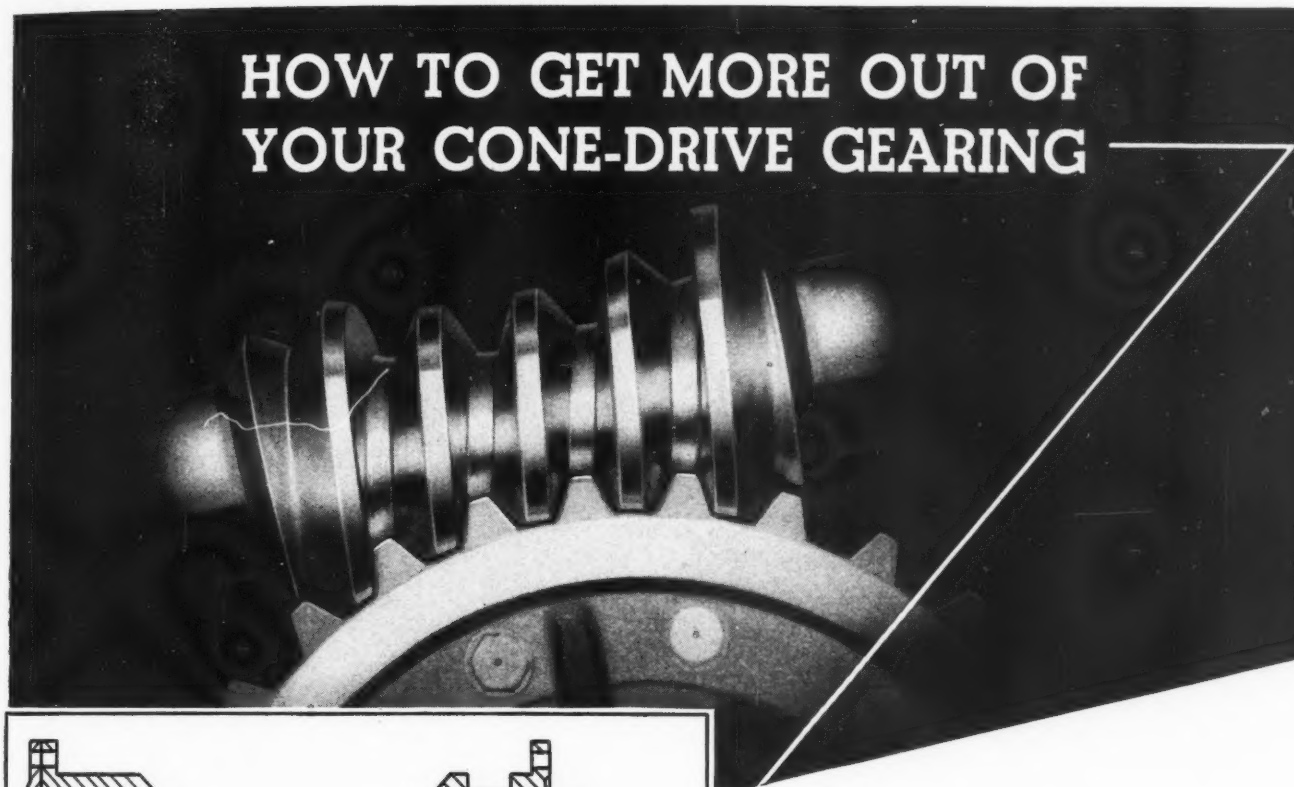
A requirement for a mechanism of this type is that it shall be capable of reclosing the breaker promptly, under some conditions in not over 20 cycles (1/3 second). This mechanism meets the demand by retaining a positive mechanical connection between the breaker and the operating piston at all times so that, at any time desired, air admitted to the cylinder will immediately act to close the breaker, regardless of whether it may have reached the full open position or not. A single lever hinged at one end, and carrying a roller at the other end to be held under the hook-shaped latch when the breaker is closed, is attached both to the piston and to the breaker pull rod at the center.

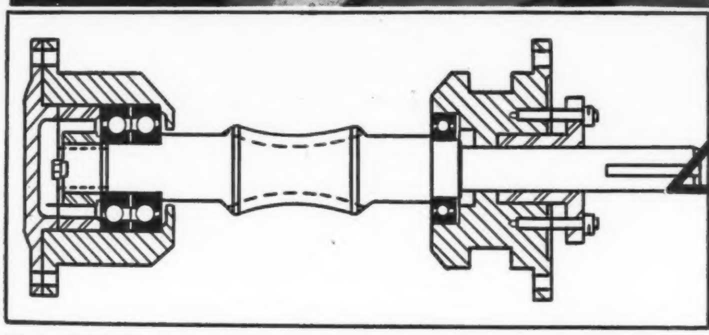
Opening Is Independent of Air Pressure

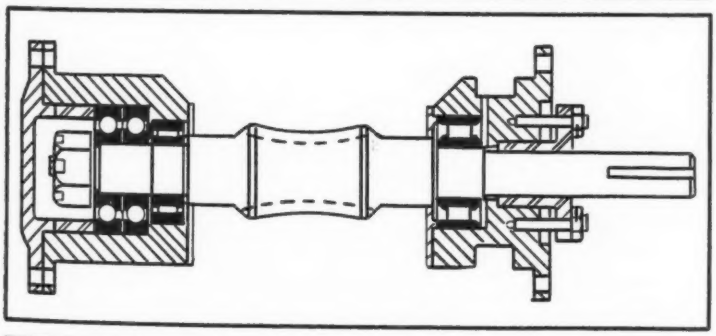
The breaker is closed under the effect of the compressed air and latched in the closed position so that the air can be cut off at the end of this stroke. When the breaker is called upon to open, the latch is released by a trip magnet and the usual accelerating spring on the breaker furnishes the impetus needed to secure the proper contact opening speed. The opening is, therefore, independent of the condition of the air supply, and required interrupting time of the breaker is controlled entirely by the mechanical time of unlatching the mechanism and accelerating the contacts by springs which were preloaded during the closing stroke of the breaker.

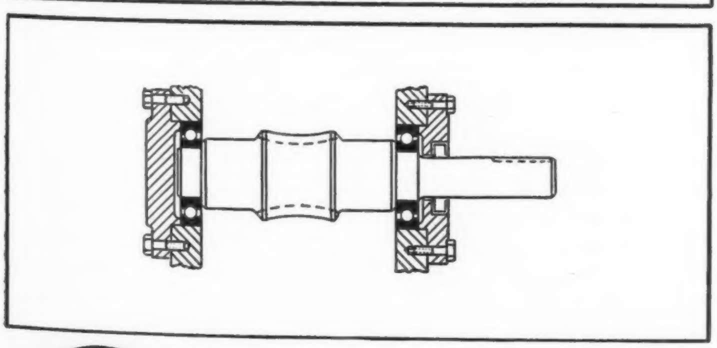
Experience with solenoids has shown that it is necessary

HOW TO GET MORE OUT OF YOUR CONE-DRIVE GEARING









. . by using correct bearing mountings

With CONE-DRIVE, smaller gearsets may be used than normally, due to the higher load capacity resulting from the double-enveloping characteristics of this form of gearing (Worm gearing is "single enveloping"; Helicals are non-enveloping).

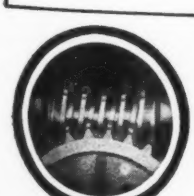
Cone-Drive's smaller size is sometimes deceptive to the designer laying out bearing mountings.

Most satisfactory mounting for Cone-Drives (top, left) consists of a duplex ball bearing at one end to take thrust and radial load, with pure radial load ball bearing at the other end.

For the larger sizes (center) use duplex ball bearing for thrust end only and roller bearings for radial load at both ends.

Both types eliminate pre-load variations due to differential expansion.

The third type shown (bottom) should not be used unless sizes are quite small (3 in. C.D. or less) and loads are light.



CONE-DRIVE DIVISION MICHIGAN TOOL COMPANY
7171 E. McNichols • Detroit, U.S.A.

Substituting Materials in Gear Design

(*Continued from Page* 69)

re-quench temperature by 100 degrees Fahr. over a standardized temperature for a low-alloy steel increased the Izod impact from 28 to 50 foot-pounds.

An extremely high core toughness is not a primary requisite for gears, as had been thought for a number of years, and except for a few isolated applications, pot or direct quenching is entirely suitable for industrial carburized gears. As illustrated, the full hardening steel will produce considerably less distortion than the carburized steel. In many instances, the increased capacity due to reduction in dynamic loading will provide greater capacity than the higher hardness case-carburized product. This point warrants careful consideration when using the NE steels.

Internal Stress-Relief Important

Experience with a manganese-molybdenum steel similar to NE 8020, although of lower manganese, has shown good results both from the standpoint of distortion and service. Core strengths of over 110,000 pounds per square inch are consistently secured and are satisfactory, although not equaling the 125,000 pounds per square inch secured with AISI 4119 or 140,000 pounds per square inch obtained with SAE 2315.

Internal stress in steel is proportional to the severity of the quench and the degree of internal stress relief obtained in the tempering operation. Here again, the amount and balance of the alloys plays an important part. Undoubtedly, a great source of trouble which will remain hidden if only casually investigated after failures of NE steels, will be the tendency to extend the range of the lower hardening alloys by drastic quenches without properly tempering to relieve the internal stresses and obtain a stabilized metallographic structure.

Hardenability Is Controlling Factor

Since the ultimate hardness or tensile strength is found to control the engineering properties of gear steels, the hardenability of the new NE steels is of primary importance. This is being given more consideration lately and much of the information on NE steels is released in the form of hardenability data. Although many engineers assume this information to be complex, it is in fact very simple and capable of direct application. It is possible that during the present emergency, steels might have to be ordered and delivered on the basis of hardenability rather than chemical analyses.

Early studies of hardenability involved the quenching of various sized bars and then sectioning these bars and exploring the hardness gradient in the cross section. The results were plotted as illustrated in *Fig.* 5. Research indicated that the hardness obtained at any point was proportional to the rate of cooling (degrees Fahr. per second

(*Continued on Page* 152)

(*Continued from Page* 146)

through the critical temperature) at that point for the alloy under consideration.

A test was later developed called the "end quench" or "Jominy" hardenability test consisting of impinging a stream of water on the end of a one inch bar as illustrated in *Fig.* 6. Naturally the cooling rate varies from a drastic water quench (200 to 300 degrees Fahr. per second) on the end surface to a slow (4 degrees Fahr. per second) air cool at the opposite end. The tests of the cooling rate at various distances from the end produced values also shown on *Fig.* 6. Plotting the rockwell C hardness from the end of the water quenched face gives a measure of the response of the steel under test to hardening at various cooling rates. It is, therefore, possible to reconstruct the hardness gradient across any size section merely by plotting the hardness obtained from the end quench specimen to the cooling rate of the point in question. It is obvious that one test is capable of giving results equal to many previously used tests involving the sectioning of several diameters with different types of quench. The speed with which the test can be completed and the minimum material used is the reason why the hardenability of NE steels is so widely reported in the form of "end quench" hardenability tests.

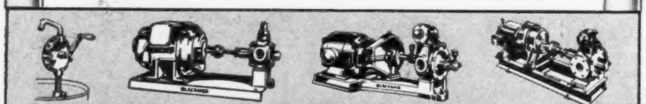
Heat Treatment Offsets Low Alloying Content

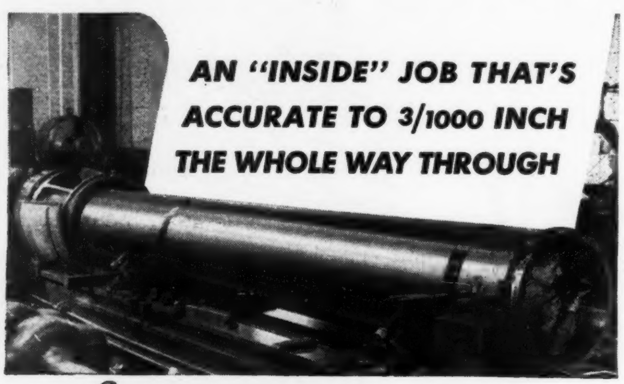
As a practical example of the usefulness of this information, a number of "end quench" hardenability curves are plotted in *Fig.* 7. The heavy solid lines show the range of "end quench" results secured with a low alloy manganese-chrome-molybdenum steel successfully used for many thousands of gears and pinions. The results illustrate that high alloy contents are not a necessity for gears if the material is properly treated. The hardenability curves are marked as good, fair, and poor, to identify heats which responded in like manner when subject to the standard oil quench heat treating procedures intended to obtain a maximum of 260 brinell for sections up to 8 inches in diameter. Included also are the hardenability curves for straight carbon and various NE alloy steels.

Using this curve, it is easily concluded that an NE 8739 will undoubtedly cause trouble when substituted for large diameter because of insufficient hardenability. The solution lies in using a water quench for large sections. The NE 8744 and NE 8749 will be satisfactory, whereas the NE 8949 with a very high hardenability must be carefully watched to prevent quenching cracks for pinions or gears having excessive changes in section and sharp fillets.

Size of Section Determines Severity of Quench

For small sections approximately 1½ inches when oil quenched and 2 inches quenched in water represented by ½-inch from the quenched end, all the steels shown will be satisfactory when maximum tempered hardnesses of 360 brinell are used. If SAE 1045 or SAE 1050 steel is used, obviously an ordinary water quench is not sufficiently drastic and a brine or other solution of faster cooling rate is required. The cooling rates of various sized sections are shown in *Fig.* 8 and can be used for comparative studies. The end quench test results are ca-





pable of being applied with accuracy to individual applications.[2]

The end quench test and other hardenability data are particularly useful for bar sizes under 5 inches diameter which respond to a liquid quench. When larger sizes, up to 30 inches, are involved, liquid quenching is not utilized because of the physical impossibility of adequately liquid quenching, excessive danger of cracking and hazard of introducing too high an internal stress. To minimize these difficulties, a heat treatment involving a simple air cool is required. Under these circumstances, a single cooling rate is secured and the resulting hardenability is only dependent upon the alloy content.

The most popular normalizing steels were a 3½ per cent nickel with or without .20-.50 molybdenum and the chrome-nickel-molybdenum steels of .50-.80 chromium, 1.5-2 nickel and .25-.40 molybdenum. The carbons usually ranged between .35 and .50 per cent. It might appear that little could be accomplished towards conserving alloys under the conditions of the slow cool. However, an examination of the effects of the various alloys upon hardenability indicates that nickel contents above one per cent do not contribute greatly to hardenability; in fact, the nickel could be reduced to .80 per cent minimum, without great effect. Falk has made this change in a chrome-nickel-molybdenum analysis to conserve nickel and found no difference in the resulting physicals with identical heat treatment.

Quenching Rate Affects Transformations

It must be realized that the mechanism of metallographic transformations is entirely different for air-quenched than for liquid-quenched steels. The principles involved are too complex to describe in this paper,[3] but are illustrated by *Fig.* 9, which shows the hardness as water, oil and liquid quenched and tempered for a manganese-molybdenum cast steel. The resulting hardness of the air quenched specimen is substantially identical to the quenched hardness regardless of the tempering temperature. Hence, hardness specifications for medium to large sections liquid quenched should not exceed 240 brinell.

It is expected that the NE alloy steels will require greater care in heat treatment to produce uniform results. For example, an alloy range specified as .20-.40 is subject to 100 per cent variation based upon the low limit and slight variations between heats result in substantial percentage differences. The high alloys previously used were not subject to such variations within the given normal specification ranges. Hence, the old high-alloy steels could be abused in heat treatment by quenching within large variations in temperatures, yet ending with substantially uniform results. The use of high alloys was sometimes merited economically from the standpoint of production uniformity. The new NE steels will demand greater attention and provisions for such attention will provide adequate returns.

It will be necessary in the war effort to make a careful check on all so-called defective materials in order to minimize unwarranted rejections which might absorb considerable time for replacements. With the present perfected welding technique, there is no reason why defec-

[2]The necessary procedure is explained in the S.A.E. *Journal*, Vol. 48, No. 1.
[3]Effect of cooling rate is discussed in "Wartime Metallurgy", beginning Page 82 of this issue.—ED.

tive forgings of large size should not be repaired and salvaged by welding. As the war continues, the engineer and his associates must face the possibilities of accepting so-called "sub-quality" steels, perhaps resulting from material rejected as unsuitable for the armed services and also caused by the pace of production. It is highly desirable to adopt the proper frame of mind pertinent to this problem.

The various NE steels which can be substituted for

TABLE I

Hardenability of NE Steels

Designation	Hardenability	Designation	Hardenability	Designation	Hardenability
NE 1330†	1.71	NE 8715	2.81	NE 9437	3.65
NE 1335†	1.83	NE 8720	3.21	NE 9440	3.78
NE 1340†	1.96	‡NE 8722	3.34	NE 9442	4.19
NE 1345	2.07	NE 8735	4.14	NE 9445	4.54
NE 1350	2.18	‡NE 8739	4.26	NE 9450	5.15
NE 52100A	2.38	‡NE 8744	4.55	NE 9537*	6.41
NE 52100B	2.98	‡NE 8749	4.80	NE 9540*	6.95
NE 52100C	3.22	‡NE 8949*	7.50	NE 9542*	7.16
NE 8020	1.47	NE 9255	1.83	NE 9550*	7.75
‡NE 8022	1.56	NE 9260	1.89	NE 9630	3.12
‡NE 8339	2.49	NE 9262	3.21	NE 9635	3.36
‡NE 8442*	3.02	NE 9415	2.22	NE 9637	3.46
NE 8613	2.51	NE 9420	2.53	NE 9640	3.58
NE 8615	2.57	NE 9422	2.64	NE 9642	3.95
NE 8617	2.62	NE 9430	3.28	NE 9645	4.06
‡NE 8620	2.94	NE 9435	3.53	NE 9650	4.27
‡NE 8630	3.52				

*Recommended for large sections only.
†The same as, or closely similar to, old A.I.S.I. 1942 numbers.
‡The same as, or closely similar to, steels of the same designation on first list of "National Emergency Alternate Steels" issued early in 1942.

standard SAE or AISI analyses are suggested in the table previously referred to.[4] TABLE I gives the maximum diameter which will harden satisfactorily. These data can be used as a guide for commercial manufacture. The Army, Navy and Air Corps have issued and are preparing lists showing allowable NE steels which can be substituted for their previously issued specifications.

The necessity for substituting materials will continue for the duration. We cannot adopt a standardized NE steel with any assurance that it will be available when needed for the manufacture of any particular part. The whole scheme of NE steels is based upon a flexible system wherein changes can be made to conserve valuable alloys for either a greater length of time or for some necessary application in combatant equipment. It can be stated reliably that the future holds no possibilities that the production of alloying elements will in any manner approach sufficient quantities to enable a return to the higher alloyed steels for the duration, nor is there any assurance that the quantities of alloys in the present NE steel will not be further reduced. Nickel production will not be able to meet the demands of the NE analyses, and molybdenum will be further restricted since domestic and foreign needs can hardly be met by our domestic supply. Manganese and chromium are in a slightly better position if carefully husbanded. Vanadium, tin and copper are definitely on the "scarce" list.

It is, therefore, apparent that full cooperation between the engineer and metallurgist are required to expedite production by the fullest use of carbon and NE steels. The substitution of materials is a necessary part of the war program.

[4] MACHINE DESIGN, October, 1942, Pages 150 and 151.—ED.

Code for Working Stresses

(*Continued from Page* 74)

by placing $S_1 = -S_2 = S_s$, where S_s is the shear strength in torsion. Then

$$r_s = \frac{r_c}{1 + r_c} \quad \text{(i)}$$

where $r_s = S_s/S_t$ and $r_c = S_c/S_t$.

The variation in r_s with change in the values of r_c, as required by Equation *i*, is shown in *Fig*. 4. Tests on thin-walled cast iron tubes in torsion indicate that this theory gives a reasonable approximation with results on the safe side of the test values. The test point in *Fig*. 4 represents values obtained by Draffin and Collins.[6]

If stress concentration is considered, Equations 7 can be written

$$\left.\begin{matrix} K_1S_1 = -S_c \ , \ K_1S_1 = S_t \\ K_1S_1 - r_cK_2S_2 = S_c \end{matrix}\right\} \quad (8)$$

To represent the combined stress effect it is desirable to write Equations 7 in terms of the stress ratios $R_1 = S_2/S_1$ and $r_c = S_c/S_t$, that is,

$$\left.\begin{matrix} \dfrac{S_1}{S_t} = r_c \ , \ \dfrac{S_1}{S_t} = 1 \\ \dfrac{S_1}{S_t} = \dfrac{r_c}{1 - r_c R_1} \end{matrix}\right\} \quad (9)$$

Equations 9 are shown plotted in *Fig*. 5 for various values of the stress ratio r_c. The equivalent strength S_1 can be selected direct from *Fig*. 5 for any stress ratio R_1.

Considerations for Triaxial Stresses

TRIAXIAL STRESSES—DUCTILE MATERIALS: For ductile materials subject to triaxial stresses S_1, S_2 and S_3, there are no conclusive experiments available. For this reason it is desirable to be cautious and to use a conservative theory. Under certain combinations of stress the distortion-energy theory gives unreasonably high strength values. Therefore, the more conservative strain-energy theory is recommended. This theory has also the desirable feature that it agrees closely with the distortion-energy theory in the case of two-dimensional stresses. By the strain-energy theory the strength relation is

$$S_{yp}^2 = S_1^2 + S_2^2 + S_3^2 - 2m(S_1S_2 + S_2S_3 + S_1S_3) \quad (10)$$

where m = Poisson's ratio. To represent the combined stress effect, Equation 10 can be represented in terms of the stress ratios R_1 and R_2 as follows:

$$\frac{S_1}{S_{yp}} = \frac{1}{\sqrt{1 + R_1^2 + R_2^2 - 2m(R_1 + R_1R_2 + R_2)}} \quad (11)$$

where $R_1 = S_2/S_1$ and $R_2 = S_3/S_1$.

Equation 11 is plotted in *Fig*. 6 for various values of Poisson's ratio. In this way the strength S_1 can be se-

lected for any given stress ratios R_1 and R_2.

When the stress components are not principal stress values but normal stresses S_x, S_y, S_z and shear stresses S_{xy}, S_{yz}, S_{xz}, the relation between the stresses is given in the following:

$$S_{yp}^2 = S_x^2 + S_y^2 + S_z^2 - 2m(S_xS_y + S_yS_z + S_zS_x) - 2(1+m)(S_{xy}^2 + S_{yz}^2 + S_{zx}^2) \quad \ldots\ldots\ldots\ldots (12)$$

Triaxial Stresses—Brittle Materials: The internal friction theory can be used for three-dimensional stresses S_1, S_2 and S_3 provided the stresses S_1 and S_2 are selected as the maximum and minimum principal stress values respectively. Equations 7, 8 and 9 can then be used for triaxial stresses and brittle materials. *Figs.* 1, 2, 4 and 5 represent the equivalent strength ratios S_1/S_{yp} or S_1/S_t for different materials and stress combinations. These diagrams also show the influence of the combined stress on the equivalent simple tensile strength since simple tension is represented by an ordinate equal to one. The value of S_1 thus obtained can now be substituted for S in Equation 1 to obtain the working stress S_w.

References

1. For references on experimental methods of stress analysis, see, for example, Frocht, M. M.—*Photoelasticity*, John Wiley & Sons, 1941; Beggs, G. E. and Timby, E. K.—"Interpreting Data from Strain-Rosettes", *Engineering News Record*, March 10, 1938; Osgood, W. R.—"Determination of Principal Stresses from Strains on Four Intersecting Gage Lines", R. P. 851, *Journal* National Bureau of Standards, Vol. 15, Page 597, 1935.
2. A bibliography on theories of failure and a development of the theories are given by many, as, for example, Timoshenko, S.—*Strength of Materials*, Vol. 2, 1941, Van Nostrand Book Company; Marin, J.—*Mechanical Properties of Materials and Design*, McGraw-Hill Book Company, 1942.
3. This definition for brittle and ductile materials has been proposed by Soderberg. See Soderberg, C. R.—"Factor of Safety and Working Stress", *Transactions* A.S.M.E., A.P.M. 52-2, 1930. See also *Transactions* A.S.M.E., Vol. 55, Page 131, 1933; and Vol. 57, Page 106, 1935.
4. See "Terms Relating to Methods of Testing", A.S.T.M. *Standards*, 1939, Part III, Pages 551-556.
5. Roark, R. J.—*Formulas for Stress and Strain*, McGraw-Hill Book Co., 1938.
6. Draffin, J. O. and Collins, W. L.—"Mechanical Properties of a High-Strength Cast Iron", *Proceedings* A.S.T.M., Vol. 39, 1939, Page 589

Design Abstracts

(*Concluded from Page* 144)

to provide them with mechanically trip-free linkages so as to permit full opening speed without the contacts being delayed by the magnetic drag of the closing solenoid. The mass of the solenoid core also acts as a drag to prevent full opening speed. These difficulties are not present in the air mechanism when a light piston is used, and when some means are provided for dumping from the operating cylinder the air still under pressure so it will not restrict the opening speed of the contacts. The latter demand is met by a series of exhaust ports on the side wall of the main cylinder, near the fully closed position, which are opened simultaneously with the operation of the breaker trip coil. The collapse of pressure is so fast that less than 25 pounds pressure remains in the cylinder at the time the contacts part. The extreme speed of this dump valve is secured by utilizing the high pressure air on the end of the cylindrical valve after it has once been cracked by a pilot piston or small magnet. (*Abstract of a paper by R. C. Cunningham and A. W. Hill, Westinghouse Elec. & Mfg. Co., presented at the recent A.I.E.E. summer convention.*)

BUSINESS AND SALES BRIEFS

IN LINE with the recently increased business of Foote Bros. Gear & Machine Corp., Chicago, several promotions have been announced. These are that of Russell G. Davis as vice president of the company, F. A. Emmons as assistant general manager, R. B. Moir as manager of sales and engineering, W. H. Ostring as special representative, Galen Butterbaugh in charge of speed reducer sales, T. F. Hill in charge of gear sales, and Charles Look as assistant in gear sales. Mr. Davis will continue in his capacity of general manager of the industrial gear division.

♦

Whitney C. Collins has been made vice president in charge of sales policy of Elastic Stop Nut Corp. He has been a director of the company since 1940.

♦

Associated with Allis-Chalmers Mfg. Co. since 1933, Selden H. Gorham has been appointed manager of dealer sales. For the past six years he has been in charge of sales and production for the feed water treatment department.

♦

Manufacturers Promotion Service Inc., 101 Park avenue, New York, has been made Eastern representative for The Elmer E. Mills Co., and will specialize in the sale of thermoplastic tubing and fittings.

♦

Former manager of the Los Angeles office of Westinghouse Electric & Mfg. Co., A. E. Hitchner has been appointed assistant to the manager of the company's industry sales departments with headquarters at East Pittsburgh.

♦

Formerly manager of engineering sales of Federal Products Corp., Fred C. Tanner has been promoted to vice president of the company.

♦

F. M. Hoefler, former vice president and general manager of Harvill Aircraft Die Casting Corp., Los Angeles, has been named president.

♦

National Malleable & Steel Castings Co., Cleveland, has announced the appointment of Charles H. McCrea as president. Mr. McCrea joined the company at Toledo as special engineer in 1913.

♦

Previously general manager of sales for Steel & Tubes division of Republic Steel Corp., William J. Sampson Jr. has been named president of The American Welding & Mfg. Co., Warren, O.

♦

To undertake a special assignment in the manufacturing division, A. C. Treece, head of the Chicago sales of-

fice of General Electric Co., has been moved to Pittsfield, Mass. T. E. Giblin, assistant manager of sales, moves from headquarters at Pittsfield to the Chicago sales office, 840 South Canal street.

♦

Formation of a new department, known as the Technical Sales Service division, has been announced by Celanese Celluloid Corp., the plastics division of Celanese Corp. of America. This department will serve the plants new to plastics that are using the company's materials to replace others they were using.

♦

Succeeding the late C. W. Fletcher, Elbert E. Husted has been elected president, Titeflex Metal Hose Co., Newark, N. J. He joined the organization in 1924 and represented the firm in a sales capacity until 1930, at which time he was made sales manager. In 1936 he was named vice president and two years later, general manager.

♦

Election of William G. Hume, formerly general manager of sales of the Pittsburgh Steel Co., as vice president of the Reynolds Wire Co., Dixon, Ill., has been announced by the company. Mr. Hume has also been chief of the rod and wire products unit of the Iron and Steel Branch of the War Production Board.

♦

According to a recent announcement, Charles C. Chamberlain has been named general sales manager of Jenkins Bros. Mr. Chamberlain has been with the company since 1929.

♦

Until recently in charge of the New York sales division of Monsanto Chemical Co., Charles Reeves is now with the Washington branch. A. C. Martinelli, connected with the sales department for New Jersey territory, is assistant manager of the Plastic division, New York sales office of that company.

♦

Formerly of Allied Plastics, A. G. Hartman is in charge of the newly formed plastics division of Plastic and Rubber Products Co., Los Angeles.

♦

Removal of offices to an enlarged plant at 27-27 Jackson avenue, Long Island City, N. Y., has been made by Seamlex Co. Inc., makers of metal hose.

♦

Because the manager of Kinney Mfg. Co. branch office in Dallas, Texas, has resigned, this office will be closed. All business and correspondence previously handled by the Dallas office will be handled from the nearest office or the home office of the company in Boston.

♦

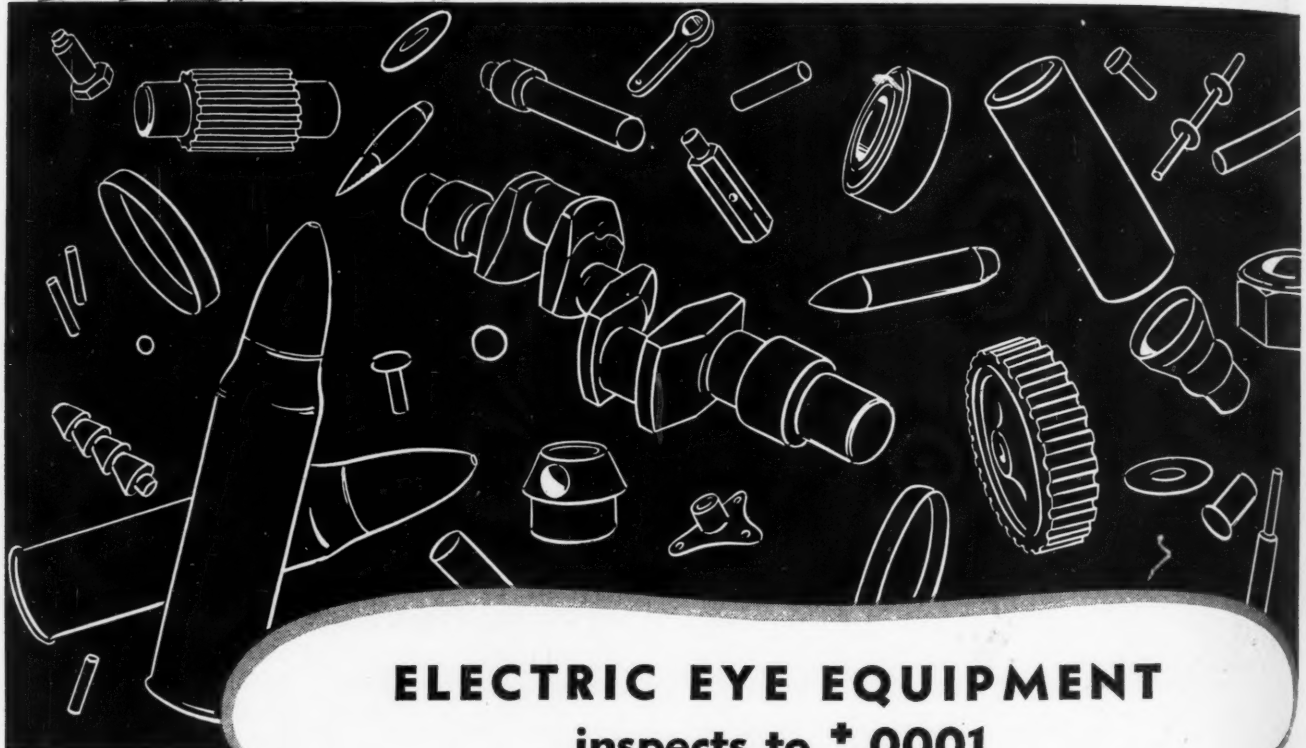
Announcement has been made that Dayton Insulating Molding Co. is now in its new plant at 207 East Sixth street, Dayton, and that the company will maintain two plants for the duration.

♦

Transfer of Joseph A. Voelker to the Pittsburgh office of Pittsburgh Steel Co. as general manager of sales has been announced. He was formerly New York district

(*Concluded on Page* 170)

Inspection PROBLEMS ARE UNNECESSARY



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(Concluded from Page 164)

sales manager. W. F. Boore who has been associated with the latter office for several years is now acting district sales manager there, replacing Mr. Voelker. The company has also transferred L. A. Ver Bryck, district sales manager at Pittsburgh, to Washington as its sales representative. J. G. Smith has been made acting district sales manager at Pittsburgh and also continues his duties as compliance co-ordinator for the purchasing department. For many years district sales manager at Houston, A. S. Vandervoort Jr. is now commissioned as a captain in the Army Air Corps, and is replaced by Paul R. King.

Tight Closure Co., Milwaukee, has established itself in the plastics field as custom molders of thermosetting plastic parts.

Equipped to do both thermosetting and thermoplastic molding, the Tri-State Molding Co. has been formed at Henderson, Ky.

MEETINGS AND EXPOSITIONS

November 11-14—

Society of Naval Architects and Marine Engineers. Fiftieth annual meeting to be held at the Waldorf-Astoria, New York. J. H. King, 29 West Thirty-ninth street, New York, is secretary.

November 16-18—

American Institute of Chemical Engineers. Thirty-fifth annual meeting to be held at the Netherland Plaza hotel, Cincinnati. S. L. Tyler, 50 East Forty-first street, New York, is executive secretary.

November 24-29—

National Chemical Exposition and Industrial Chemical Conference. Meeting to be held at the Sherman hotel, Chicago. Marcus W. Hinson, National Chemical Exposition, 110 North Frankline street, Chicago, is manager.

November 30-December 2—

American Society of Refrigerating Engineers. Annual meeting to be held at Hotel Commodore, New York. David L. Fiske, 37 West Thirty-ninth street, New York, is secretary.

November 30-December 2—

American Society of Agricultural Engineers. Annual meeting to be held at Stevens hotel, Chicago. Raymond Olney, Box 229, St. Joseph, Mich., is secretary.

November 30-December 4—

American Society of Mechanical Engineers. Sixty-third annual meeting to be held at Hotel Astor, New York. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

November 30-December 5—

Exposition of Power and Mechanical Engineering. Exposition to be held this year at new location, Madison Square Garden, New York. Charles F. Roth, 480 Lexington avenue, New York, is manager.

NEW MACHINES—

And the Companies Behind Them

(For illustrations of other outstanding machinery, see Pages 90-91)

Armament

Parachute fabric inspection machine, Hermas Machine Co., Hawthorne N. J.
Automatic shell degreaser, Phillips Mfg. Co., Chicago.

Chemical

Machine for controlling atmospheric moisture in tanks, Pittsburgh Lectrodryer Corp., Pittsburgh.

Finishing

Alloy sprayer, Alloy Sprayer Co., Detroit.
Reciprocating electric sanding machine, Detroit Surfacing Machine Co., Detroit.
Magnetic log washer, Stearns Magnetic Mfg. Co., Milwaukee.

Heat Treating

Aluminum heat-treating furnace, Despatch Oven Co., Minneapolis.
Flame hardening machine, Hydraulic Machinery Co., Detroit.

Industrial

Recirculated type steam generator, Vapor Car Heating Co. Inc., Chicago.
Electric furnaces, Cooley Electric Mfg. Corp., Indianapolis.

Materials Handling

Heavy-duty locomotive type crane truck, Baker-Raulang Co., Baker Industrial Truck Division, Cleveland.
Electric-hydraulic telescopic lifter, Service Caster & Truck Co., Somerville, Mass.

Metalworking

*Horizontal boring mill, Yoder Co., Cleveland.
*High-speed precision automatic, The Wickman Corp., Detroit.
*Rotary milling machine, Snyder Tool & Engineering Co., Detroit.
(*Illustrated in pictorial spread, Pages 90-91.)
*Abrasive cut-off machine, Challenge Machine Co., Grand Haven, Mich.
*Gear finisher, National Broach & Machine Co., Detroit.
*Variable speed lathe, Schauer Machine Co., Cincinnati.
*100-ton capacity press, Denison Engineering Co., Columbus, O.
Supersensitive drill press for light work, Edward Blake Co., Newton Centre, Mass.
Dual head radial tapping machine, Bakewell Mfg. Co., Los Angeles.
Dynamic balancing machine, Bear Mfg. Co., Rock Island, Ill.
Swiss type screw machine, The City Engineering Co., Dayton, O.
Vari-angle miller, Shields Mfg. Co. Inc., Long Island City, N. Y.
Ram type turret lathe, International Machine Tool Corp., Elkhart, Ind.
Double-end milling and centering machine, Sundstrand Machine Tool Co., Rockford, Ill.
Wet tool grinder, Hammond Machinery Builders, Kalamazoo, Mich.
Ball bearing headstock lathe, J. G. Blount Co., Everett, Mass.
Semiautomatic cylinder turning lathe, Sparks Machine Tool Corp., Norwalk, Conn.
Twist drill grinder, Howe & Son Inc., Hinsdale, N. H.

Office

Automatic rotary gelatin duplicator, Ditto Inc., Chicago.
Intercommunication system, Talk-A-Phone Mfg. Co., Chicago.

Pumping

Streamlined top feed, bottom discharge pump, T. Shriver Pump & Co., Harrison, N. J.
High-pressure starting pump, Watson-Stillman Co., Roselle, N. J.
Electric-hydraulic barrel pump, Trabon Engineering Corp., Cleveland.
Portable forced-induction pump, Lincoln Engineering Co., St. Louis.

Testing

Hosiery abrasion tester, U. S. Testing Co. Inc., Hoboken, N. J.
Photoelectric meter for measuring reflectance and color, Photovolt Corp., New York.
Optical comparator, Portman Machine Tool Co., Mount Vernon, N. Y.
Spring tester, John Chatillon & Sons, New York.
Tensile testing machine, W. C. Dillon & Co. Inc., Chicago.
*Lead measuring instrument, Sheffield Corp., Dayton, O.

Welding

Radial spot welder, Sciaky Bros., Chicago.
Low pressure welding gun, Progressive Welder Co., Detroit.
Arc-control station, Wilson Welder & Metals Co., New York.
Exhauster and ventilator, Chelsea Fan & Blower Co., Irvington, N. J.
Alternating current welder, Allis-Chalmers Mfg. Co., Milwaukee.
*Forge welder, Progressive Welder Co., Detroit.